U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 111.

B. T. GALLOWAY, *Chief of Bureau*.

MISCELLANEOUS PAPERS.

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[a] The five papers constituting this bulletin were issued in separate form on July 6, September 9, October 31, December 7, and December 28, 1907.

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MISCELLANEOUS PAPERS.

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THE LARKSPURS AS POISONOUS PLANTS.[a]

By Albert C. Crawford, *Pharmacologist, Poisonous-Plant Investigations.*

INTRODUCTION.

Throughout the United States many species of larkspur (Delphinium) occur. Some of these form an important feature of the western landscape;[b] others, such as *Delphinium ajacis*, on account of their beauty have been cultivated in gardens, from whence they have escaped and become a pest to the farmer.[c]

The genus Delphinium is in a very confused condition botanically and needs revision.[d] However, the botanical characteristics of the genus are clearly marked and constitute sufficient reason for considering any plant bearing them as deserving of suspicion. *Delphinium trolliifolium* Gray, represented in the accompanying illustration (Plate I), shows these characteristics. In Canada[e] and in our Western States, especially in Colorado and Montana, various species of Delphinium have been accused of stock poisoning, although feeding experiments with these plants have varied in their results, and opinion in the West has been by no means uniform as to their poisonous properties. According to Wilcox,[f] in Montana 600 sheep were poisoned by *Delphinium menziesii* on one ranch, of which 250 died. In India the

[a] Of the many kinds of plants of the western ranges poisonous to stock, various species of larkspur are among the most destructive, especially in the mountainous regions of Colorado, Wyoming, and Montana.

About two years ago a study of the poisonous properties of one of the most common species was undertaken cooperatively by the Colorado Agricultural Experiment Station and the Office of Poisonous-Plant Investigations, the field collections and field tests being carried on by Dr. George H. Glover, veterinarian of the station, and the technical laboratory studies by Dr. A. C. Crawford, Pharmacologist, under the direction of Dr. R. H. True, Physiologist in Charge of the Poisonous-Plant Investigations of the Bureau of Plant Industry. The principal results of Doctor Crawford's work are here summarized.

It is shown that this larkspur is most virulent in its early stages and becomes much less active toward flowering time. The importance of the functions of elimination in bringing about recovery is also clearly indicated, and the significance of this fact in harmonizing the varying results of different investigations is pointed out.—B. T. Galloway, *Chief of Bureau.*

[b] Meehan, T. Delphinium Bicolor. Meehan's Monthly, vol. 12, p. 1. 1902.

[c] Rept. Comr. Agr. for 1865, p. 510.

[d] Huth, E. Monographie d. Gattung Delphinium. Bot. Jahrb., vol. 20, p. 322. 1895.

[e] Noxious Weeds and How to Destroy Them. Government of Northwest Territory, Dept. Agr. Bul. 2, p. 27. 1900.

[f] Chesnut, V. K. Preliminary Catalogue of Plants Poisonous to Stock. Ann. Rept. Bur. Animal Ind., 1898, p. 400.

dew from *D. brunonianum* is said to poison stock, and *D. vestitum* is claimed to be poisonous to goats.[a] Similar reports come from France.[b] Chesnut and Wilcox, in particular, have brought this subject to public attention, Wilcox's field notes and post-mortem records being especially suggestive.[c]

The main symptoms seen in the poisoning of sheep by *Delphinium menziesii* were a stiffness of the limbs, with awkward gait; associated with this were involuntary muscular twitchings and loss of muscular coordination. Convulsions with marked rapidity in the pulse rate occurred. The respiration became shallow, but finally rapid. Wilcox fed the chloroform and benzol extracts of the dried plant to sheep, causing typical symptoms. He also called attention to larkspur poisoning in cattle.[d] This work was continued by Chesnut and Wilcox.[e] They fed and injected extracts of tall larkspur (*Delphinium glaucum*) and of purple larkspur (*D. bicolor*); but although these extracts produced some symptoms in rabbits and in sheep they failed to kill.

Nelson pastured a sheep during May in an area in which *Delphinium menziesii* was growing. This sheep ate all the Delphinium she could obtain herself, and in addition was fed 1,133.92 grams more, but showed no symptoms. A second sheep was fed 1,111.3 grams of the fresh plant in five days, but showed no symptoms. During the experiment this animal was deprived of all feed save the Delphinium.[f] Irish[g] experimented by feeding the plants growing in May to steers, feeding the tops of 24 plants of *D. trolliifolium* to one and the roots to another without results. He also fed 30 plants of white larkspur without results. He fails to state, however, how long his feeding continued. Glover's experiments[h] with rabbits were rather misleading, some dying, but most survived. Gerlach[i] fed *D. consolida* to sheep without results.

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[a] Watts, G. Dictionary of Economic Products of India, vol. 3, pp. 64, 70. 1890.

[b] Delaford, P. Traitè sur la maladie de sang des bêtes à laine, Paris, 1843, p. 173.

[c] Wilcox, E. V. Larkspur Poisoning of Sheep. Montana Agr. Expt. Sta. Bul. 15. 1897.

[d] Wilcox, E. V. Poisonous Plants of Montana. Montana Agr. Expt. Sta. Bul. 22, p. 45. 1899.

[e] Chesnut, V. K., and Wilcox, E. V. Stock-Poisoning Plants of Montana. U. S. Dept. Agr., Div. Botany, Bul. 26, p. 65. 1901.

[f] Nelson, S. B. Feeding Wild Plants to Sheep. Proc. Sec. Ann. Meeting Assoc. Expt. Sta. Veterinarians. 1898. U. S. Dept. Agr., Bur. Animal Ind., Bul. 22, p. 11.

[g] Irish, P. H. Plants Poisonous to Stock. Oregon Expt. Sta. Bul. 3, p. 25. 1889.

[h] Glover, G. H. Larkspur and Other Poisonous Plants. Colorado Agr. Expt. Sta. Bul. 113, p. 17. 1906.

[i] Dammann, C. Gesundheitspflege, 1886, p. 841.

DELPHINIUM TROLLIIFOLIUM, GRAY.

LABORATORY EXPERIMENTS WITH DELPHINIUM CAMPORUM.

Specimens of *Delphinium camporum* were sent from Fort Collins, Colo., for testing in the laboratory of Poisonous-Plant Investigations. Five grams of the dried and powdered plant were accurately weighed and then extracted over night with 20 c. c. of water and 10 c. c. of 95 per cent alcohol. The alcohol was added mainly as a preservative. The following day the extraction and squeezing were continued until the fluid became colorless. The fluid was evaporated on the next day in vacuo at about 40° C., and the residue was dissolved in water and made up to 30 c. c.—perfectly arbitrary figures. Of this aqueous solution 1 c. c. injected subcutaneously into a guinea pig weighing 730 grams caused no disturbance, and 3 c. c. were also without effect, whereas 6 c. c. killed the same guinea pig in 55 minutes. A solution of 4 c. c. injected into a guinea pig weighing 352 grams caused no symptoms, while 6 c. c. injected into another guinea pig weighing 285 grams killed in 33 minutes. Later, 5 c. c. killed a guinea pig weighing 196 grams in 55 minutes, while 4 c. c. injected into a guinea pig weighing 299 grams gave no symptoms. Evidently the lethal dose of this solution lies between 4 and 5 c. c. The solution used in the above experiments was made from plants collected on April 26, 1905.

On May 16 another lot of material was collected, and a solution corresponding to 4 c. c. of the first batch was injected into a guinea pig weighing 455 grams without producing any symptoms. However, 5.3 c. c. of this solution killed a guinea pig weighing 350 grams, but a much longer period elapsed before death occurred than with the extract of the first material.

In June another lot of material was collected, and a solution of this corresponding to 4 c. c. caused no symptoms in a guinea pig weighing 376 grams; 5.3 c. c. caused no symptoms in a guinea pig weighing 500 grams, and 6.6 c. c. was inactive in a guinea pig weighing 480 grams. Of the dried material 10 grams were then extracted, and killed a guinea pig weighing 320 grams only after about 10 hours. A control amount of plain distilled water failed to kill. The lethal dose is evidently much higher than in the second stage.

There is no question as to the fact that Delphinium when injected subcutaneously will kill, and these experiments also establish the fact that the plant loses much of its toxicity as it approaches the flowering stage. It has been noted that *Delphinium consolida* is also less active when mature.[a]

Just after flowering, the purple larkspur turns yellow and ceases to

[a] Dammann, C. Gesundheitspflege, 1886, p. 1072.

be attractive, so that there is less danger of poisoning,[a] although Chesnut and Wilcox report a death in cattle from eating *Delphinium glaucum* in September.[b] The great danger early in the season seems to arise from the fact that the Delphinium appears early in the spring, and the ground may again be covered with snow, so that it is the only green plant in sight, and therefore when in an especially poisonous stage it is eaten by cattle.

A rabbit weighing 2,409.66 grams was fed January 28, 1907, with a concentrated aqueous extract corresponding to 16.66 grams of the dried plant in the second stage. No symptoms resulted. On January 30 the animal weighed 2,377.15 grams.

On January 28, 1907, a second rabbit, weighing 1,658.35 grams, was fed with a similar extract of 33.33 grams, but no symptoms resulted. Two days later the animal still weighed 1,658.35 grams.

On February 1, 1907, the first rabbit was fed an aqueous extract of 80 grams, and it died in 53 minutes with convulsions. Previous to death, paralysis of the voluntary muscles was well marked. The stomach of this animal was markedly reddened.

A rabbit weighing 1,984.41 grams on February 6, 1907, was starved 24 hours and then fed an extract of 50 grams of the same plant at 9.45 a. m. At 11.50 a. m. the animal was dull and was lying with its chin resting on the floor; at 12.25, legs paralyzed; 3.04, the animal urinated, chin still resting on the floor; 3.57, the animal could push itself around with hind legs. The following day the rabbit appeared normal. On February 11 it weighed 1,899.39 grams; February 12, 1,956.07 grams; February 13, 2,012.75 grams; March 11, 1,984.41 grams.

On February 13, 1907, a well-fed rabbit, weighing 2,097.77 grams, which had been in the laboratory for some time, was fed by stomach tube an aqueous extract of 50 grams of the same plant. This animal was observed continuously for 6 hours and appeared perhaps only slightly duller. He ate during the night, and weighed 2,119.94 grams on February 14. During the night no stools were passed. On February 16 this rabbit weighed 1,970.24 and on February 21, 2,012.75 grams.

The urine passed the first 24 hours after feeding was alkaline. Some of this was shaken with chloroform and on evaporation was taken in acid water. On evaporating off the acid, the watery solution was injected subcutaneously into a guinea pig weighing 467.76 grams, but produced no symptoms. The urine secreted in the following 24

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[a] Wilcox, E. V. Plant Poisoning of Stock in Montana. U. S. Dept. Agr., Bur. Animal Ind., 17th Ann. Rept., 1900, p. 96.

[b] Chesnut, V. K., and Wilcox, E. V. Stock-Poisoning Plants of Montana, p. 67.

hours was added to the first and the whole shaken out with benzol. This, after taking up with acid water, was injected into the same guinea pig. The animal soon became very dull, walking with waddling gait when forced to move, being evidently affected by the poison. Two days later the animal was normal. The urine of a control rabbit, similarly shaken with benzol, produced no such symptoms in this guinea pig.

On February 11, 1907, an aqueous extract of 5 grams was injected subcutaneously into a rabbit weighing 666.14 grams. An hour and three minutes later the animal was unable to stand, and soon developed convulsive movements of the limbs. This animal was expected to die at any time during the afternoon, but gradually improved and appeared slightly duller than normal the following day. On February 13 it weighed 613.61 grams; February 25, 595.29 grams; and on March 16, 552.78 grams, showing a steady diminution in weight.

An extract of 9.5 grams injected subcutaneously into a rabbit weighing 2,182.79 grams was without immediate effect.

An aqueous extract of 20 grams when injected into a rabbit weighing 481.93 grams soon caused paralysis of the limbs, and the rabbit died in 32 minutes.

On February 11, 1907, a rabbit weighing 1,417.46 grams was opened under ether, and the mouths of the ureters were tied off, together with the bladder, to prevent elimination by the urine. An aqueous solution corresponding to 34 grams of the same plant was then fed by mouth. This animal remained dull all the afternoon, and at 4.45 p. m., 4 hours and 45 minutes after the feeding, he was resting with his chin on the cage. He was found dead and stiff at 9.15 p. m., having evidently died some time previous. A post-mortem showed the ureters distended and sharply outlined.

Another rabbit weighing 1,743.37 grams was prepared in a similar manner by tying off the ureters and bladder and was fed with an extract of 50 grams. In 1 hour and 47 minutes this animal was paralyzed and unable to stand, breathing very slowly, and died 6 minutes later. The ureters were found dilated as in the previous case, and the stomach was slightly reddened.

A control for these two rabbits was prepared in a similar manner at the same time as the others. Nine hours after the operation, when the two rabbits which were fed the Delphinium were dead, this rabbit was bright and running about, but was then killed with chloroform to prevent suffering.

In these cases it is necessary to consider not only the effects of non-elimination but also the fact that the power which the liver possesses of storing up and removing injurious bodies from the circulation may

be interfered with, as Mosse[a] has proved that starved and nephrectomized rabbits show histological changes in the liver cells.

On February 20, 1907, a well-fed rabbit weighing 1,403.29 grams was etherized for 12 minutes and then fed an extract of 50 grams to see if the increased toxic action of the plant was due to any interference with the metabolism caused by the ether. On February 23 this animal showed no symptoms, weighing 1,360.78 grams, and on February 25 the weight was 1,403.29 grams. The urine collected in 60 hours was shaken with benzol, as it had previously been found that much, if not all, of the active principles of *Delphinium camporum* goes into the alkaline benzol shaking by the Dragendorff method. The residue from the benzol evaporations was then taken up with acetic acid water. On removing the acid by heat a few drops were injected into the dorsal lymph sac of a male frog (*Rana clamitans*) weighing 35 grams. This animal soon became paralyzed and was unable to move, but recovered over night. The following day a few more drops were injected with the same result, showing that some of the active principle of the Delphinium was eliminated with the urine.

From these experiments it can be seen that aqueous extracts of *Delphinium camporum* will kill rabbits on subcutaneous injection, and also by mouth if the dose is large, while much smaller doses will kill if the elimination is interfered with, as by tying off the ureters, or after starving, a condition which intensifies the action, probably by accelerating absorption. What seems to be the cause of the uncertainty in the results, especially in the lack of striking results in the feeding experiments, is that no consideration was given to the fact that the poisoning in this case may be simply the resultant of the excretion and absorption of the plant; in other words, that very little of the plant may be taken up by the gastro-intestinal tract and that this may be eliminated by the kidneys before a poisonous dose has been absorbed, so that the question of poisoning becomes one of rapidity of absorption. This is well known to be the case with curare, where the administration by mouth, except in large doses, is not likely to prove poisonous unless the elimination is interfered with as by tying the ureters.[b] Consequently the conditions most favorable for poisoning on the range would be those which aid the more thorough extraction of the poisonous principle from the plant by the gastro-intestinal tract, thus favoring absorption, and those which interfere with the elimination by the kidneys or interfere with the storing of the poison by the liver, as renal and hepatic disease or lack of salts, which normally increase diuresis.

[a] Mosse, M. Ueber Leberzellenveränderungen nephrektomierter u. hungernder Thiere. Zeits. f. Klin. Med., vol. 60, p. 373. 1906.

[b] Brunton, T. L. Text-Book of Pharmacology, 3d ed., London, 1893, p. 38.

A striking feature about these rabbits is that in some cases while the dose was not sufficient to kill immediately they gradually lost in weight, probably a direct result of the irritation of the gastro-intestinal tract. This condition may find its parallel in stock removed from a Delphinium area. Knowles[a] and Wilcox[b] have claimed that the inhalation of a few drops of ammonia and the hypodermic injection of atropin, $\frac{1}{60}$ to $\frac{1}{4}$ gram (1 mg. to 15 mg.) for sheep, or 1 gram (60 mg.) for cattle, is the most effective medicinal treatment. Elimination by purgatives and diuretics may aid. If possible, absorption from the gastro-intestinal tract should be hindered, perhaps by lard, but the real treatment is preventive.

One member of the genus Delphinium, *D. staphisagria*, has been studied carefully, and a number of bases (delphinin, delphinoidin, staphisagrin) isolated, but much is still to be desired in the way of exact knowledge concerning these bodies.[c] Delphinin has a local irritative action. Its systemic action is mainly paralytic on the heart and respiration, and resembles that of aconitin in many respects.[d] Post-mortem examinations in poisoning by mouth with this body showed marked reddening of the stomach. In a number of Van Praag's experiments with feeding solutions of Delphinium a marked increase in urinary secretion was noted.[e] *Delphinium consolida* has also received some attention chemically,[f] while *D. leroyi*, *D. peregrinum*, and *D. mauritanicum* have been shown to produce poisoning experimentally.[g]

Recently *Delphinium bicolor*, *D. menziesii*, *D. nelsonii*, and *D. scopulorum stachydeum* have been found to yield an alkaloid, delphocurarin,[h] which has been introduced as a substitute for curare in

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[a] Knowles, M. E. Larkspur Poisoning in Sheep and Cattle. New York Med. Jour., vol. 66, p. 271. 1897.

[b] Wilcox, E. V. Larkspur Poisoning of Sheep, p. 45.

[c] Dragendorff and Marquis. Ueber d. Alkaloide des Delphiniums staphisagria. Arch. f. Exp. Path. u. Pharmakol., vol. 7, p. 55. 1877.

Kara-Stojalow, C. Ueber d. Alkaloide d. Delphinium staphisagria. Pharm. Zeits. f. Russland, 1890, vol. 29, pp. 628, 641, 657, 673, 689, 705, 721.

[d] Tamburini, N., and Leone, A. Azoine fisiol. della Delfinina. Gior. Internaz. d. Sci. Med., n. s., vol. 3, p. 985. 1881.

Orfila, M. Traité de toxicologie, 5 ed., vol. 2, p. 138. 1852.

[e] Van Praag, J. L. Delphinin. Arch. f. Path. Anat., vol. 6, p. 439. 1854. Sereck. J. Beitr. z. Kennt. d. Delphinins. Dorpat Diss. 1874.

Darbel, A. Recherch. Chim. et physiol. sur les alcaloides du Delphinium staphisagria. Montpellier. Thèse. 1864.

[f] Masing, E. Ueber d. Alkaloid d. Feldrittersporns. D. consolida. Pharm. Zeits. f. Russland, vol. 22, p. 33. 1883.

[g] Rochebrune, A. T. de. Toxicol. Africane, vol. 1, pp. 152, 161, 353. 1896.

[h] Feinde der Haustiere und ihre giftige Principen (Delphocurarin). Pharm. Centr., vol. 44, p. 913. 1903.

vivisection work, and this introduction is indorsed by Lohmann's work.[a]

Schiller[b] corroborates Lohmann's results, but claims that curare is efficient for muscle physiological work in smaller doses than is the delphinin of Heyl.

This use of Delphinium certainly offers a field which should be investigated commercially, as curare is likely to be uncertain in its action.[c] Methyl delphinin is said also to possess this curare-like action.[d]

The coloring matter of the flowers of *Delphinium zalil* has been utilized as a dye.[e] Other Delphiniums, such as *D. ajacis*, have been recommended for insecticidal uses, and especially on account of cheapness.[f]

Froggatt states that common garden larkspur will kill locusts, and advises planting them in masses around gardens and orchards to protect against the ravages of these insects.[g] The same claim is made as to its action against grasshoppers.[h]

Delphinium coeruleum has been used to kill maggots and *D. brunonianum* to destroy ticks.[i] This latter plant has been used to some extent as a substitute for musk.

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[a] Lohmann, A. Unters. über d. Verwerthb. eines Delphinin präp. an Stelle d. Curare in d. muskelphys. Technik Pflüger's Arch. f. Ges. Physiol., vol. 92, p. 473. 1902.

[b] Schiller, V. Ueber d. physiol. Wirkungen d. Delphinins (Heyl). Arch. f. Anat. u. Physiol., Physiol. Abtheil., p. 248, 1904.

[c] Merck, E. Ann. Reports, 1902, vol. 16, p. 48.

[d] Kobert, R. Lehrb. d. Intox., 2d ed., p. 1185.

[e] Aitchison, J. E. T. Some Plants of Afghanistan. Pharm. Jour. and Trans., vol. 17, p. 466. 1887.

[f] Amer. Jour. Pharm., vol. 55, p. 50. 1883.

[g] Froggatt, W. W. Plague Locusts. Agr. Gaz. New South Wales, vol. 11, p. 181. 1901.

[h] Bailey, J. F. Hemp. Queensland Agr. Jour., vol. 2, p. 200. 1898.

[i] Watts, G. Dictionary of Economic Products of India, vol. 3, pp. 64–65. 1890.

THE FIBERS OF LONG-STAPLE UPLAND COTTONS.

By H. A. Allard, *Scientific Assistant, Cotton Breeding Investigations.*

UNIFORMITY OF COTTON FIBERS.

In investigations in cotton breeding where an improvement in certain lint characters is desired several factors must be carefully considered. Among these, some of the most important are fineness of lint, the relative yield of lint to the total yield of seed cotton, and the uniformity of length of all the fibers when properly combed out and examined. The last character, uniformity of length, is a most important one and has much to do with subsequent waste and the production of good yarns in the process of manufacture.

On Plate II are illustrations of cotton seeds with fibers combed out to show uniformity and nonuniformity in the length of the fibers. The seeds to the left (A) show very poor uniformity and are of the "butterfly" type, as they are commonly called. In marked contrast, the seeds to the right (B) show excellent uniformity as a result of several generations of careful selection.

APPARENT LACK OF UNIFORMITY AND ITS OCCURRENCE.

There is an apparent lack of uniformity which deserves considerable attention from the standpoint of cotton growers and breeders. Plate III illustrates this character, although it is more strikingly brought out in the operation of detaching the seed from the lock. From the illustration there would appear to be a great lack of uniformity, due to a group of fibers about twice the length of the general covering. This group arises from the center of the main body of fibers or, often, from those having a point of attachment near the larger end of the seed. This character is usually associated with the finer, more crinkly types of long-staple cottons, such as the fine, long-linted Egyptian and Sea Island varieties and the long-staple Upland varieties—Griffin, Allen, Cook, etc. It is a character which becomes more apparent as a variety is being rigidly selected generation after generation for finer, longer staple. This has been well illustrated in the improvement of the lint characters of the Russell variety and, to some extent, the Jones variety. The orginal condition

of both of these varieties is remarkably free from this so-called longer group of fibers. In the case of the greatly improved Russell strain, which has become distinctive enough in good lint characters and yield to be designated as a new variety—the so-called Columbia cotton—these longer fibers are evident to a remarkable degree.

THE TRUE NATURE OF THE LONGER FIBERS.

It has been more or less the rule with cotton breeders and cotton growers acquainted with the requisites of desirable lint characters to regard these extra-long fibers as an unfavorable feature. In this light they meant a variation toward nonuniformity. In the work of selection, to avoid as much as possible a perpetuation of this sort of variation, plants showing this character most markedly were regarded with suspicion and later even discarded, although in other respects they were among the best in the field.

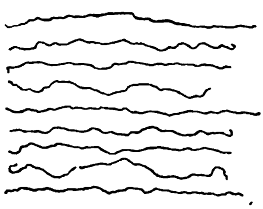


FIG. 1.—Single cotton fibers from the so-called longer group of fibers.

A careful examination leads to the conclusion that these fibers should be regarded in a wholly different light. *They are not longer fibers as they have been generally considered, but are caused by more or less curling and interweaving, which results in the pulling out of fibers from adjacent seeds.*

In the ordinary manner of stretching the locks to determine the drag, the fibers are slowly separated and drawn out, and at those points of greatest binding, as shown in Plate II, C, *a*, *b*, and *c*, the groups of longer fibers appear to rise. If, now, a single seed is selected and detached from the rest and the entire group of fibers loosened from its attachment to the seed coat in the neighborhood of the longer groups, one can with fine forceps draw these fibers out carefully and compare their length with those of the rest of the seed.

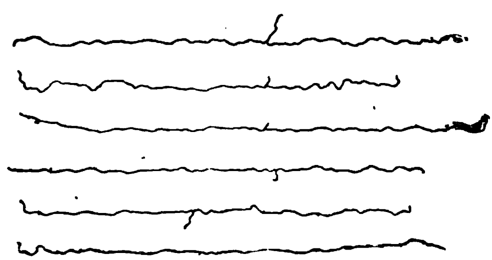
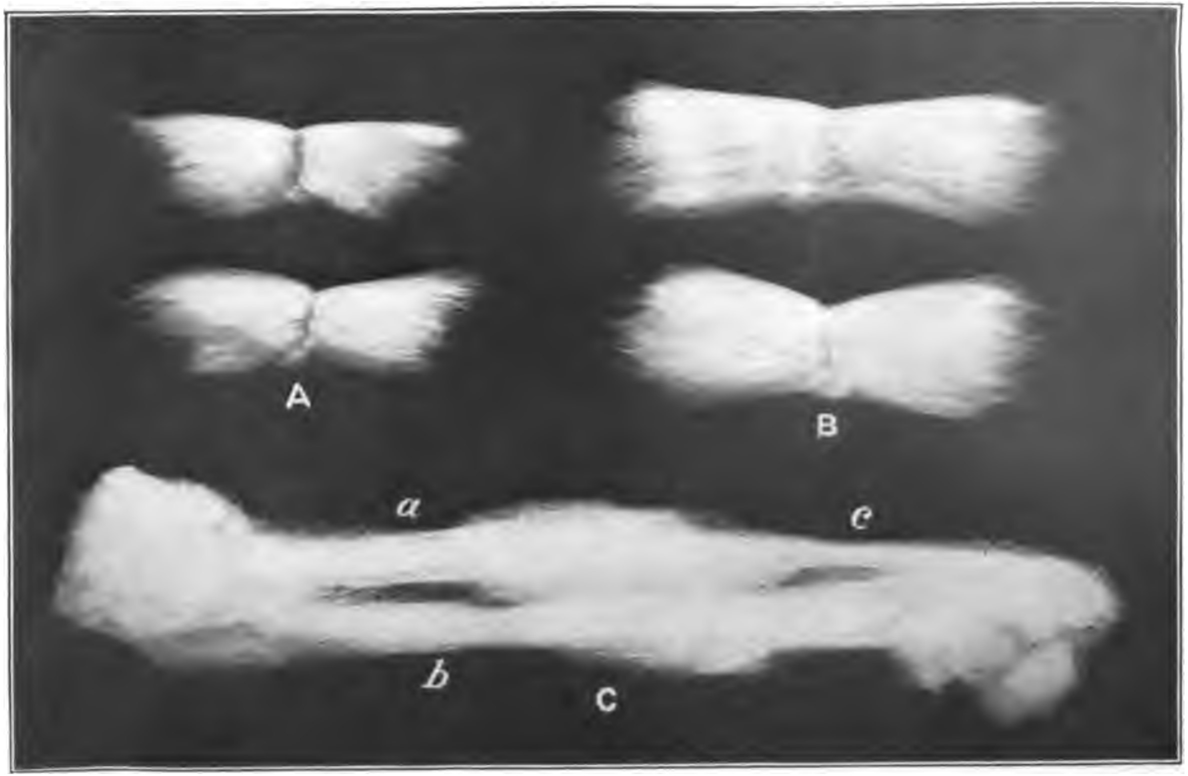


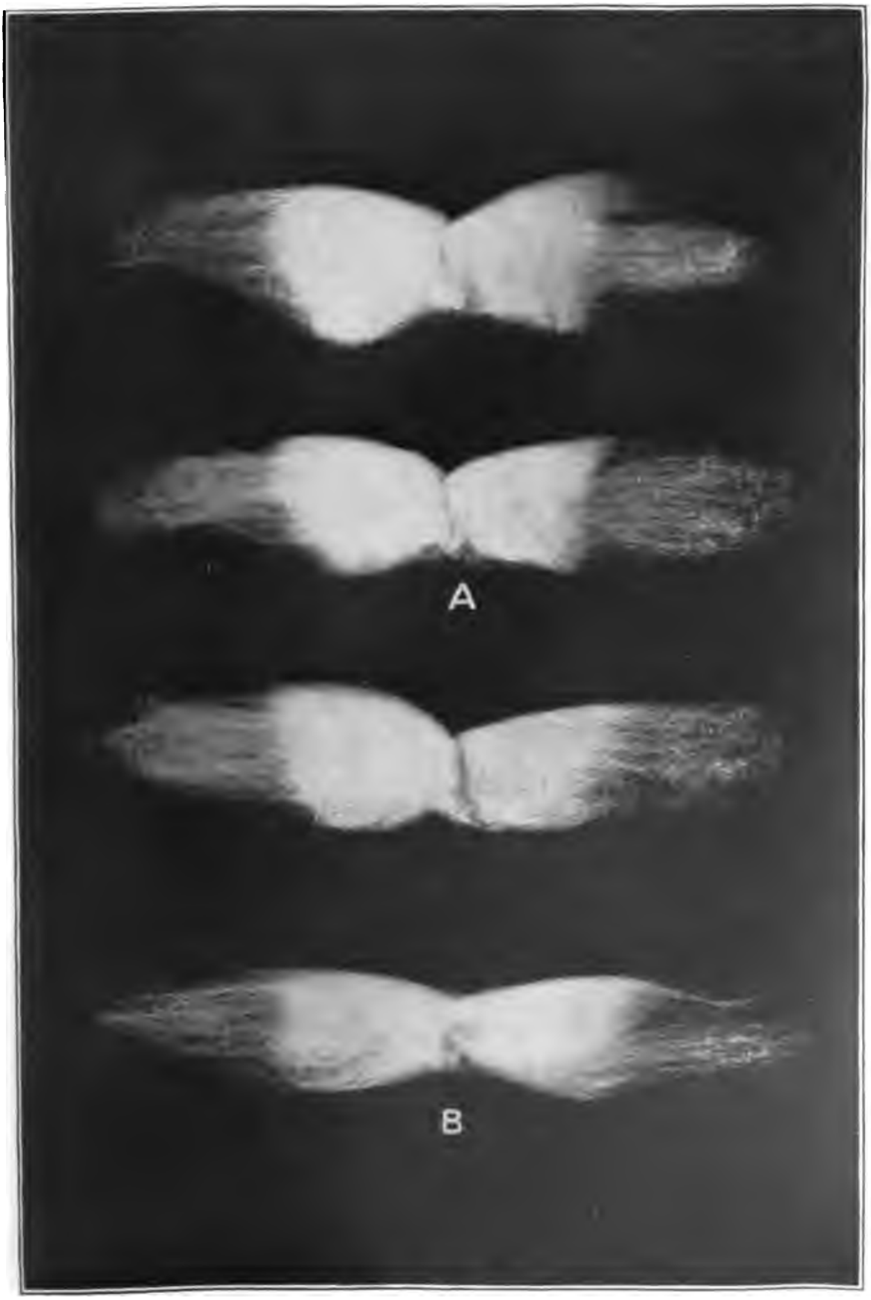
FIG. 2.—A few extra-long cotton fibers, showing two fibers united.

In many instances the single fibers now readily separate, since the tension of pulling has ceased. Several of these single fibers are shown in figure 1. In some instances fibers nearly twice the normal length are drawn out. Oftentimes with the naked eye the point of union or tying may be discerned by the tiny loose ends, as is shown in figure 2. In other cases, however, this point of union is so intimate that only a high microscopic power can make it evident. Figure 3 illustrates various



COTTON SEEDS WITH FIBERS ATTACHED.

A and *B*.—Cotton seeds with fibers combed out to show uniformity and nonuniformity in the length of the fibers. *C*.—Lock of Griffin cotton stretched so as to show points of origin of longer fibers—*a*, *b*, and *c*.



SEEDS OF COTTON COMBED OUT TO SHOW THE SO-CALLED LONGER FIBERS.

A.—Columbia variety. *B.*—Griffin variety.

degrees of this tying or curling together, as seen when greatly magnified. In figures 1 and 2 single and united fibers, respectively, of natural length are shown, but the diameters are of necessity much greater than normal, owing to the exceeding fineness of the fibers.

The drag of cottons showing the longer fibers previously described gives a more extended, elastic tension than is manifest among the short-staple varieties. It is probable that breeders may find this character a useful one in indicating a tendency toward increased length, fineness, and crinkliness of staple in the individuals in which it occurs most noticeably—an indication of better spinning quality.

It is important that breeders and growers of long-staple cottons should know that these apparently longer fibers are no indication of true lack of uniformity. The presence of these fibers in the long-staple Upland varieties has quite universally led to the erroneous belief that such cottons are rather inferior in uniformity as regards length of fibers. The Griffin cotton, in particular, recognized in other respects as the best long-staple Upland cotton grown, has always been described as decidedly unsatisfactory so far as uniformity in length of staple is concerned, since the drawing out of fibers from adjacent seed is a marked characteristic of this variety.

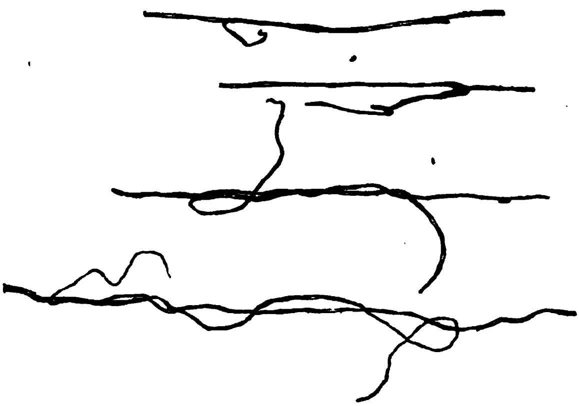


FIG. 3.—Cotton fibers tied together, very much magnified.

A knowledge of the true nature of these longer fibers will clear the reputation of some of the best long-staple Upland varieties of a serious fault hitherto wrongly attributed to them by all breeders and growers.

IMPORTED LOW-GRADE CLOVER AND ALFALFA SEED.

By Edgar Brown, *Botanist in Charge of Seed Laboratory*, and Mamie L. Crosby, *Assistant, Seed Laboratory.*

INTRODUCTION.

During the calendar year 1906 the United States exported 3,615,873 pounds of clover seed, and during the latter half of the same year imported 6,306,561 pounds, the exports for the year being only a a little more than one-half the imports for six months. The same condition holds true with alfalfa seed, the imports far exceeding the exports. The relatively large importation of these seeds results from short crops in this country and a constantly increasing demand on account of the new land being brought under cultivation and the extension of diversified farming.

Illustrations of typical samples of imported red clover and alfalfa seed of good quality and that of low grade are shown in Plate IV.

WHY LOW-GRADE SEED IS IMPORTED.

In Europe seed testing has been gradually growing in favor for forty years and is now recognized as an important aid to agriculture. All the European countries, with the exception of Spain and Turkey, have seed-testing stations, varying in number from one in Italy to twenty-eight in Germany. Each of them has the necessary equipment for making complete tests of seed, both for mechanical purity and for germination.

The test for mechanical purity as conducted in these stations includes not only the determination of the percentage of pure seed and of other seeds and dirt, but also the size and source of the seed. The source of the seed is determined by the characteristic weed seeds which are found. While errors are no doubt made, these determinations are of great value in showing that at least a part of the seed was raised in a certain section, and they furnish information as to the probable adaptability of the seed to local conditions. Through the work of these stations the people have come to appreciate the importance of good seed, and as the greater part of that now used in Europe is sold on the basis of accurate tests for mechanical purity and germination the sale of low-grade seed has been greatly reduced.

A similar condition exists in Canada, where there is a strict law governing the quality of seed sold. In this country, however, only

three States have any effective legislation restricting the sale of seeds within their borders. Several of the agricultural experiment stations are preparing to undertake seed testing, but their equipment is limited and the number of samples handled is small. At present there are no Federal restrictions on the importation of low-grade and worthless seed. As a natural result the United States has become the dumping ground for the poor seed of Canada and Europe.

ANALYSES OF IMPORTED LOW-GRADE SEEDS.

RED CLOVER.

Table I gives the analyses of sixty-one lots of low-grade red clover seed imported during the fiscal year ended June 30, 1906, amounting to 990,809 pounds. The total importations of red clover seed for the same period amounted to 7,498,287 pounds, so that the low-grade seed furnished about one-eighth of the total. These low-grade importations contained seed enough to sow approximately 125,000 acres at an average rate of seeding. This seed is for the most part small-sized, light-weight screenings. A practical failure must be expected whenever seed of this quality is used, either from not securing a stand on account of poor germination or from smothering with introduced weeds.

TABLE I.—*Analyses of 61 samples of low-grade red clover seed imported during the year ended June 30, 1906.*

Number of seed sample.	Red clover seed.	Other seeds.	Dirt and broken seed.	Dodder present.[a]	Kinds of weed seeds.	Weight of 1,000 red clover seeds.	Germination of red clover seed.	Quantity imported.[b]	Price per 100 pounds at which seed was imported.	Live red clover seed (seed that germinated) in sample.	Actual cost of 100 pounds of red clover seed that germinated.
	Per cent.	*Per cent.*	*Per cent.*		*Number.*	*Milligrams.*	*Per cent.*	*Pounds.*		*Per cent.*	
2945	48.06	25.78	26.16	No.	39	882	38	6,740	$5.20	18.26	$28.48
2946	66.1	13.16	20.74	Yes	27	900	91	5,027	7.60	60.15	12.63
2947	77.43	9.44	13.13	Yes	32	1,135	83	6,876	9.10	64.27	14.16
3101	72.5	25.73	1.77	No.	10	1,594	96.5	3,750	11.00	69.96	15.72
3159	73.14	10.38	16.48	Yes	25	893	88.5	16,535	8.00	64.73	12.36
3222	73.8	7.88	18.32	Yes	24	810	89	13,380	7.20	65.68	10.96
3395	70.41	10.90	18.69	Yes	20	779	76.5	30,857	7.00	53.86	12.99
3400	75.78	9.35	14.87	Yes	28	895	80	32,706	7.75	60.62	12.78
3425	70.05	21.89	8.06	No.	33	1,377	77.5	32,630	8.00	54.29	14.73
3432	74.39	15.02	10.59	Yes	50	951	75.5	22,000	8.00	56.16	14.24
3456	43.03	19.31	37.66	Yes	39	855	28.5	25,300	2.80	12.26	22.84
3457	46.24	19.09	34.67	Yes	32	818	27.5	35,347	6.10	12.72	47.95
3488	63.31	23.22	13.47	No.	29	913	68	35,350	5.80	43.05	13.47
3566	69.81	12.25	17.94	Yes	23	847	72	32,893	7.50	50.26	14.92
3571	67.89	16.67	15.44	No.	29	995	66.5	29,490	9.20	45.15	20.37
3587	67.55	13.50	18.95	Yes	45	898	60.5	7,015	7.10	40.87	17.37
3588	76.74	14.53	8.73	Yes	39	952	63.5	12,498	7.60	48.73	15.59
3591	70.6	12.59	16.81	Yes	30	839	21.5	13,119	3.50	15.18	16.27
3598	74.73	12.68	12.59	Yes	40	1,102	75.5	33,069	8.25	56.42	14.62
3647	64.84	11.69	23.47	Yes	32	885	68	32,562	7.70	44.09	17.46
3696	64.09	13.79	22.12	Yes	36	840	62.5	44,029	11.50	40.05	28.71
3721	72.55	20.67	6.78	No.	19	1,143	75.5	32,523	7.60	54.77	13.88
3755	65.65	18.48	15.87	No.	33	885	52.5	6,550	5.50	34.47	15.96
3810	65.52	19.23	15.25	Yes	23	977	48.5	15,588	6.40	31.78	20.14

[a] 75.41 per cent of samples contained dodder.
[b] Total quantity of low-grade red clover seed imported, 990,809 pounds.

FIG. 1.—ALFALFA OF GOOD QUALITY.
Natural size and magnified 9 times.

FIG. 2.—IMPORTED ALFALFA OF LOW GRADE.
Natural size and magnified 9 times.

FIG. 3.—RED CLOVER OF GOOD QUALITY.
Natural size and magnified 9 times.

FIG. 4.—IMPORTED RED CLOVER OF LOW GRADE.
Natural size and magnified 9 times.

TABLE I.—*Analyses of 61 samples of low-grade red clover seed imported during the year ended June 30, 1906*—Continued.

Number of seed sample.	Red clover seed.	Other seeds.	Dirt and broken seed.	Dodder present.	Kinds of weed seeds.	Weight of 1,000 red clover seeds.	Germination of red clover seed.	Quantity imported.	Price per 100 pounds at which seed was imported.	Live red clover seed (seed that germinated) in sample.	Actual cost of 100 pounds of red clover seed that germinated.
	Per cent.	*Per cent.*	*Per cent.*		*Number.*	*Milligrams.*	*Per cent.*	*Pounds.*		*Per cent.*	
3811	57.3	22.81	19.89	Yes	45	1,021	42	15,506	$5.60	24.06	$23.27
3816	64.58	10.27	25.15	Yes	31	886	60.5	32,116	7.62	39.07	19.50
3834	77.45	7.70	14.85	Yes	28	1,087	66	33,159	9.60	51.12	18.78
3906	61.34	15.51	23.15	Yes	45	846	53	32,468	7.50	32.51	23.07
3945	67.04	17.10	15.86	Yes	36	891	67	12,474	8.50	44.91	18.93
3946	83.54	6.60	9.86	Yes	21	995	74	30,427	11.20	61.82	18.12
3959	94.04	.95	5.01	Yes	12	1,357	44.5	1,576	9.50	41.85	22.70
3960	94.15	1.77	4.08	Yes	19	1,552	69	11,288	9.90	64.96	15.24
3962	97.15	.66	2.19	Yes	11	1,538	34	12,000	8.60	33.03	26.04
3963	96.07	1.66	2.27	Yes	14	1,585	70	6,393	8.00	67.25	11.90
3964	96.32	1.93	1.75	Yes	11	1,603	72	5,952	9.10	69.35	13.12
3965	93.54	.27	6.19	Yes	9	1,422	15	2,425	4.50	14.03	32.07
3967	95.04	1.20	3.76	Yes	17	1,404	48	7,937	7.60	45.62	16.66
3994	47.49	32.08	20.43	Yes	41	909	17.5	10,995	4.70	8.31	56.56
3990	83.07	10.32	6.61	No	17	1,252	72.5	750	12.00	60.22	19.93
4009	83.87	8.02	8.31	Yes	42	1,370	46.5	11,130	8.20	38.9	21.08
4010	64.04	17.07	18.89	Yes	41	835	26	15,024	5.80	16.65	34.83
4026	68.59	17.78	13.63	Yes	20	870	86.5	4,000	14.20	59.33	23.93
4029	94.23	2.59	3.18	No	11	1,582	65.5	10,318	8.80	61.72	14.25
4031	95.41	1.76	2.83	Yes	11	1,495	54.5	2,500	8.98	51.99	17.27
4032	93.82	3.91	2.27	No	14	1,732	43.5	6,303	6.80	40.81	16.66
4035	95.52	2.16	2.32	Yes	19	1,555	27.5	3,382	7.80	26.27	29.69
4038	95.63	1.12	3.25	Yes	17	1,397	53.5	2,372	7.70	51.16	15.05
4044	67.80	14.91	17.29	Yes	43	963	31.5	32,074	7.00	21.36	32.77
4051	98.29	.41	1.3	No	5	1,597	59.5	2,551	6.90	58.48	11.79
4053	93.55	.17	6.28	Yes	8	1,434	8	1,102	4.50	7.48	60.16
4067	78.61	8.82	12.57	No	15	1,164	50	453	4.00	39.30	10.18
4084	61.09	16.93	21.98	No	19	1,236	75.5	33,866	10.10	46.12	21.90
4097	64.77	16.41	18.82	Yes	50	951	46	10,787	7.00	29.79	23.50
4118	74.04	15.18	10.78	Yes	35	1,010	60.5	2,963	7.50	44.79	16.74
4163	76.62	12.36	11.02	No	26	1,165	75.5	30,000	8.10	57.84	14.00
4165	54.44	24.57	20.99	No	37	868	38	18,200	6.00	20.68	29.01
4179	61.56	15.58	22.86	Yes	48	926	55.5	22,046	6.12	34.16	17.93
4180	61.04	12.58	26.38	Yes	27	926	75.5	4,851	7.70	46.08	16.71
4181	58.02	17.13	24.85	Yes	46	933	54	22,046	6.12	31.34	19.54
4183	77.65	8.15	14.20	Yes	38	980	87.5	7,363	9.75	67.94	14.35
4225	72.79	16.88	10.33	Yes	43	1,010	29	6,178	6.00	21.11	28.42
Average	74.06	12.17	13.83		29.7	1,105.5	58.03	....	7.61	43.16	20.39

In more than one-half of the sixty-one samples of which an analysis is given the weight of 1,000 seeds is less than a gram, while 1,000 good plump seeds weigh 1½ grams or more. These lots contain an average of only 43.1 per cent of live red clover seed and much of the seed that will germinate is worthless for seeding purposes, as it is of small size, immature, and of low vigor.

It is often claimed that seed of this kind is imported to be recleaned before it is put on the market. This, however, can not be the case, as in the importations referred to the average cost of the red clover seed that will grow is $20.39 per hundred pounds on the basis of the average import price of $7.61 per hundred pounds. At the time this seed was imported five lots of high-grade seed were offered for sale to the Department of Agriculture at an average price of $15.05 per hundred pounds, the average cost of the red clover seed that germinated being $15.59 per hundred pounds. In other words, one

hundred pounds of seed that would grow of the best quality cost $15.59, while one hundred pounds that would grow of the poorest quality was imported at a cost of $20.39.

This low-grade seed always carries a large number of weed seeds, fifty kinds being found in each of two lots. Of that from Germany all but five lots contained dodder seed.

In sowing seed of the average quality shown in Table I at the rate of 8 pounds to the acre there would be about nine weed seeds sown per square foot, including three dodder seeds to every 2 square feet.

Below is given the number of each kind of weed seeds found in the lots an analysis of which is given in Table I.

NUMBER OF WEED SEEDS TO THE POUND IN SIXTY-ONE SAMPLES OF LOW-GRADE RED CLOVER SEED IMPORTED DURING THE YEAR ENDED JUNE 30, 1906.

Sample No. 2945.—Black-seeded plantain, 95,580; lady's-thumb, 1,530; knotweed, 90; spurge, 1,440; mayweed, 450; catmint, 180; green foxtail, 4,320; yellow foxtail, 450; buckhorn, 1,890; bracted plantain, 540; chickweed, 270; curled dock, 1,260; bitter dock, 540; sorrel, 810; healall, 540; peppergrass, 360; wild carrot, 360; small crab-grass, 6,480; crab-grass, 5,670; slender paspalum, 1,350; pennyroyal, 2,700; stink-grass, 90; yellow trefoil, 540; five-finger, 180; barnyard grass, 90; spiny sida, 90; sedge, 90; three-seeded mercury, 270; vervain, 720; tumbling amaranth, 1,620; rough pigweed, 900; lamb's-quarters, 1,080; witch-grass, 7,470; spreading panicum, 990; prickly lettuce, 90; other weed seeds, 3,420.

Total weed seeds to the pound, 144,450.

Sample No. 2946.—Buckhorn, 16,200; clover dodder, 38,160; wild carrot, 5,256; healall, 4,608; low hop-clover, 648; plantain, 72; sorrel, 2,808; yellow trefoil, 144; wild chicory, 432; vervain, 432; field camomile, 360; mayweed, 72; woodrush, 72; mouse-ear chickweed, 72; lamb's-quarters, 72; hawkweed picris, 72; round-leaved toad-flax, 72; small-flowered crane's-bill, 216; bird's-foot trefoil, 72; other weed seeds, 1,728.

Total weed seeds to the pound, 71,568.

Sample No. 2947.—Buckhorn, 13,860; black-seeded plantain, 3,150; bracted plantain, 90; plantain, 90; yellow trefoil, 540; clover dodder, 3,600; Chilean clover dodder, 540; wild carrot, 3,060; sorrel, 1,350; curled dock, 270; vervain, 1,080; white vervain, 180; green foxtail, 810; lamb's-quarters, 810; healall, 630; bird's-foot trefoil, 360; hop-clover, 360; low hop-clover, 90; wild chicory, 270; kidney vetch, 90; witch-grass, 180; knotweed, 180; lady's-thumb, 90; small crab-grass, 90; ox-tongue, 90; spurry, 90; alfilaria, 90; other weed seeds, 810.

Total weed seeds to the pound, 32,850.

Sample No. 3101.—Green foxtail, 96,135; witch-grass, 1,020; plantain, 595; lamb's-quarters, 425; yellow trefoil, 595; small crab-grass, 255; lady's-thumb, 170; three-seeded mercury, 85; ragweed, 85; other weed seeds, 340.

Total weed seeds to the pound, 99,705.

Sample No. 3159.—Buckhorn, 24,130; Chilean clover dodder, 14,250; sorrel, 3,910; wild carrot, 3,910; healall, 3,825; yellow trefoil, 850; bird's-foot trefoil, 425; lamb's-quarters, 340; wild chicory, 340; ox-tongue, 340; green foxtail, 170; mayweed, 170; field camomile, 170; hop-clover, 170; mouse-ear chickweed, 85; small crab-grass, 85; low hop-clover, 170; chickweed, 85; kidney vetch, 85; red pimpernel, 85; small-flowered crane's-bill, 85; saltbush, 85; other weed seeds, 595.

Total weed seeds to the pound, 54,360.

Sample No. 3222.—Buckhorn, 93,678; clover dodder, 15,132; healall, 6,084; wild carrot, 3,276; sorrel, 2,652; yellow trefoil, 1,716; black-seeded plantain, 546; lamb's-quarters, 390; curled dock, 390; spurry, 390; bird's-foot trefoil, 312; vervain, 312; hop-clover, 234; saltbush, 156; lesser starwort, 156; mayweed, 156; white vervain, 78; chickweed, 78; ox-eye daisy, 78; green foxtail, 78; blue field madder, 78; peppergrass, 78; other weed seeds, 468.

Total weed seeds to the pound, 126,516.

Sample No. 3395.—Buckhorn, 13,940; clover dodder, 25,415; healall, 9,180; wild carrot, 5,015; sorrel, 5,490; yellow trefoil, 1,360; lamb's-quarters, 765; black-seeded plantain, 765; spurry, 425; hop-clover, 340; vervain, 255; curled dock, 255; rabbit's-foot clover, 170; wild chicory, 170; mayweed, 170; red pimpernel, 85; bird's-foot trefoil, 85; green foxtail, 85; other weed seeds, 595.

Total weed seeds to the pound, 64,565.

Sample No. 3400.—Buckhorn, 5,780; clover dodder, 8,364; sorrel, 7,790; healall, 4,592; yellow trefoil, 1,886; wild carrot, 1,558; lamb's-quarters, 656; field dodder, 410; red pimpernel, 328; hop-clover, 328; lesser starwort, 164; woodrush, 164; low hop-clover, 164; rabbit's-foot clover, 82; chickweed, 82; bitter dock, 82; small-seeded false flax, 82; vervain, 82; other weed seeds, 3,526.

Total weed seeds to the pound, 36,120.

Sample No. 3425.—Catchfly, 14,790; green foxtail, 5,780; sorrel, 4,674; buckhorn, 3,444; yellow trefoil, 3,198; curled dock, 3,280; plantain, 2,214; black-seeded plantain, 1,066; lamb's-quarters, 1,066; mayweed, 820; Canada thistle, 820; small crab-grass, 738; witch-grass, 410; mouse-ear chickweed, 410; lady's-thumb, 246; healall, 246; catmint, 164; evening primrose, 164; five-finger, 164; field cress, 164; stick-tight, 164; ragweed, 82; yellow foxtail, 164; chickweed, 82; other weed seeds, 492.

Total weed seeds to the pound, 44,842.

Sample No. 3432.—Buckhorn, 21,074; black-seeded plantain, 10,168; clover dodder, 11,316; wild carrot, 5,002; healall, 1,558; sorrel, 1,230; lamb's-quarters, 820; witch-grass, 656; yellow trefoil, 574; spreading panicum, 328; crab-grass, 410; small crab-grass, 492; chicory, 410; low hop-clover, 328; curled dock, 246; ragweed, 246; spurge, 164; mouse-ear chickweed, 164; bracted plantain, 82; forget-me-not, 82; catmint, 82; plantain, 82; barnyard grass, 82; five-finger, 82; small-seeded false flax, 82; Canada thistle, 82; red pimpernel, 246; hawkweed picris, 82; chickweed, 82; lesser starwort, 82; peppergrass, 82; bird's-foot trefoil, 82; scentless camomile, 82; other weed seeds, 1,558.

Total weed seeds to the pound, 58,138.

Sample No. 3456.—Buckhorn, 36,982; wild carrot, 36,326; yellow trefoil, 2,050; wild chicory, 4,264; clover dodder, 4,592; field dodder, 656; vervain, 2,542; healall, 1,968; low hop-clover, 82; sorrel, 984; curled dock, 410; hawkweed picris, 820; ox-tongue, 656; field camomile, 656; lamb's-quarters, 574; red pimpernel, 492; green foxtail, 410; black-seeded plantain, 164; lesser starwort, 164; Canada thistle, 82; nipplewort, 82; cat's-ear, 82; knotweed, 82; barnyard grass, 82; small crab-grass, 82; other weed seeds, 2,296.

Total weed seeds to the pound, 97,580.

Sample No. 3457.—Buckhorn, 35,700; wild carrot, 32,725; chicory, 4,845; clover dodder, 4,760; healall, 3,230; yellow trefoil, 1,785; sorrel, 1,105; lamb's-quarters, 850; green foxtail, 425; red pimpernel, 425; dodder, 425; field camomile, 340; ox-tongue, 340; curled dock, 340; hawkweed picris, 255; knotweed, 255; cut-leaved crane's-bill, 170; nipplewort, 170; black-seeded plantain, 170; mayweed, 85; lesser starwort, 85; bracted plantain, 85; spiny sow thistle, 85; other weed seeds, 5,015.

Total weed seeds to the pound, 93,070.

Sample No. 3488.—Buckhorn, 6,314; sorrel, 3,936; green foxtail, 3,198; curled dock, 2,050; lamb's-quarters, 1,640; black-seeded plantain, 1,476; plantain, 984; bitter dock, 820; catmint, 1,148; lesser starwort, 656; Canada thistle, 656; mouse-ear

chickweed, 574; mayweed, 902; lady's-thumb, 410; yellow trefoil, 328; small crab-grass, 246; stick-tight, 328; three-seeded mercury, 164; barnyard grass, 246; yellow foxtail, 164; knotweed, 82; healall, 82; witch-grass, 82; other weed seeds, 1,804.

Total weed seeds to the pound, 28,290.

Sample No. 3566.—Buckhorn, 19,890; clover dodder, 13,050; sorrel, 8,460; healall, 3,600; wild carrot, 3,420; yellow trefoil, 1,530; rabbit's-foot clover, 1,260; green foxtail, 990; low hop-clover, 630; black-seeded plantain, 450; spurry, 270; wild chicory, 270; hop-clover, 180; chickweed, 180; lesser starwort, 90; blue field madder, 90; Canada thistle, 90; small crab-grass, 90; mayweed, 90; field camomile, 90; other weed seeds, 6,300.

Total weed seeds to the pound, 61,020.

Sample No. 3571.—Green foxtail, 5,100; black-seeded plantain, 7,225; buckhorn, 3,910; plantain, 1,955; lamb's-quarters, 3,145; curled dock, 1,275; sorrel, 1,615; yellow trefoil, 2,805; witch-grass, 1,785; barnyard grass, 170; mayweed, 850; small crab-grass, 510; Canada thistle, 255; lady's-thumb, 170; mouse-ear chickweed, 170; small-seeded false flax, 85; catmint, 85; healall, 85; other weed seeds, 1,700.

Total weed seeds to the pound, 32,895.

Sample No. 3587.—Buckhorn, 23,322; wild carrot, 11,856; clover dodder, 14,742; healall, 3,042; sorrel, 2,028; lamb's-quarters, 1,560; yellow trefoil, 1,482; wild chicory, 1,248; plantain, 546; green foxtail, 468; rabbit's-foot clover, 390; low hop-clover, 312; curled dock, 312; mayweed, 234; red pimpernel, 234; evening primrose, 156; scentless camomile, 156; dove's-foot crane's-bill, 156; saltbush, 156; vervain, 3,198; small crab-grass, 156; five-finger, 156; field camomile, 156; lady's-thumb, 78; black-seeded plantain, 78; stick-tight, 78; kidney vetch, 78; frenchweed, 78; spurry, 78; ox-tongue, 78; witch-grass, 78; other weed seeds, 4,134.

Total weed seeds to the pound, 70,824.

Sample No. 3588.—Buckhorn, 24,055; dodder, 6,205; sorrel, 6,120; black-seeded plantain, 4,505; wild carrot, 2,720; healall, 2,805; lamb's-quarters, 1,615; yellow trefoil, 1,275; field camomile, 340; spurge, 510; small crab-grass, 595; low hop-clover, 425; green foxtail, 425; wild chicory, 340; bird's-foot trefoil, 340; crab-grass, 170; bracted plantain, 170; mayweed, 255; lady's-thumb, 170; lesser starwort, 85; yellow foxtail, 85; witch-grass, 85; five-finger, 85; spurry, 85; rabbit's-foot clover, 85; large-seeded false flax, 85; other weed seeds, 3,400.

Total weed seeds to the pound, 57,035.

Sample No. 3591.—Sorrel, 15,215; wild carrot, 10,710; lamb's-quarters, 9,945; buckhorn, 7,905; yellow trefoil, 4,565; healall, 2,975; catchfly, 2,295; curled dock, 2,040; black-seeded plantain, 1,785; green foxtail, 1,615; dodder, 850; kidney vetch, 510; saltbush, 425; red pimpernel, 340; small crab-grass, 340; slender paspalum, 255; wild chicory, 255; mayweed, 255; field camomile, 170; chickweed, 170; frenchweed, 170; spurry, 85; catmint, 85; lady's-thumb, 85; small-flowered crane's-bill, 85; other weed seeds, 1,020.

Total weed seeds to the pound, 64,150.

Sample No. 3598.—Sorrel, 56,706; buckhorn, 14,820; clover dodder, 18,876; wild carrot, 5,070; yellow trefoil, 2,106; healall, 1,326; lamb's-quarters, 624; green foxtail, 546; plantain, 468; wild chicory, 468; small crab-grass, 234; scentless camomile, 234; forget-me-not, 234; lesser starwort, 156; mouse-ear chickweed, 156; low hop-clover, 156; knotweed, 156; ox-eye daisy, 156; rabbit's-foot clover, 78; bird's-foot trefoil, 78; woodrush, 156; red pimpernel, 78; blue field madder, 78; cut-leaved crane's-bill, 78; saltbush, 78; field camomile, 312; other weed seeds, 1,092.

Total weed seeds to the pound, 104,520.

Sample No. 3647.—Buckhorn, 11,872; clover dodder, 25,424; sorrel, 6,608; healall, 4,592; wild carrot, 4,144; yellow trefoil, 2,352; lamb's-quarters, 784; vervain, 560; low hop-clover, 448; green foxtail, 336; small crab-grass, 336; lesser starwort, 336; red pimpernel, 336; chickweed, 224; spurry, 224; curled dock, 112; lady's-thumb, 112;

hop-clover, 112; mayweed, 112; field camomile, 112; small-seeded false flax, 112; other weed seeds, 3,584.

Total weed seeds to the pound, 62,832.

Sample No. 3696.—Yellow trefoil, 2,542; clover dodder, 29,520; buckhorn, 12,218; wild carrot, 8,528; low hop-clover, 984; hop-clover, 410; healall, 5,330; sorrel, 7,626; curled dock, 164; lamb's-quarters, 2,132; vervain, 1,066; red pimpernel, 574; lesser starwort, 574; green foxtail, 574; mayweed, 246; field camomile, 246; wild chicory, 164; kidney vetch, 164; bird's-foot trefoil, 164; spurry, 164; barnyard grass, 82; small crab-grass, 82; blue field madder, 82; wood rush, 82; other weed seeds, 3,444.

Total weed seeds to the pound, 77,162.

Sample No. 3721.—Buckhorn, 7,735; green foxtail, 4,250; sorrel, 2,380; curled dock, 2,210; lamb's-quarters, 1,615; plantain, 1,445; bitter dock, 1,275; black-seeded plantain, 850; yellow trefoil, 765; catmint, 595; Canada thistle, 425; lady's-thumb, 340; mouse-ear chickweed, 255; small crab-grass, 255; knotweed, 170; mayweed, 170; other weed seeds, 2,125.

Total weed seeds to the pound, 26,860.

Sample No. 3755.—Green foxtail, 3,740; buckhorn, 3,400; black-seeded plantain, 2,720; sorrel, 2,720; lamb's-quarters, 2,125; catmint, 1,700; curled dock, 1,615; Canada thistle, 1,190; black-seeded plantain, 1,275; yellow trefoil, 595; lady's-thumb, 510; witch-grass, 340; barnyard grass, 340; lesser starwort, 255; mouse-ear chickweed, 255; mayweed, 255; small crab-grass, 255; ragweed, 255; stick-tight, 170; ox-eye daisy, 170; chickweed, 85; wild chicory, 85; yellow foxtail, 85; three-seeded mercury, 85; small-seeded false flax, 85; other weed seeds, 2,890.

Total weed seeds to the pound, 27,200.

Sample No. 3810.—Buckhorn, 7,020; dodder, 6,930; lamb's-quarters, 4,950; green foxtail, 3,420; healall, 2,790; sorrel, 3,060; wild carrot, 2,430; yellow trefoil, 810; saltbush, 1,080; red pimpernel, 900; mayweed, 270; field camomile, 180; vervain, 90; wild chicory, 90; low hop-clover, 90; rabbit's-foot clover, 90; hop-clover, 90; bird's-foot trefoil, 90; lesser starwort, 90; sweet clover, 90; other weed seeds, 1,980.

Total weed seeds to the pound, 36,540.

Sample No. 3811.—Clover dodder, 18,700; buckhorn, 19,380; lamb's-quarters, 5,355; green foxtail, 4,080; sorrel, 3,315; wild carrot, 3,060; healall, 2,550; yellow trefoil, 1,360; saltbush, 1,190; wild chicory, 680; red pimpernel, 425; rabbit's-foot clover, 340; white campion, 170; ox-tongue, 170; hawkweed picris, 85; early winter cress, 170; Canada thistle, 85; mayweed, 85; field camomile, 85; bitter dock, 85; curled dock, 85; lady's-thumb, 85; knotweed, 85; kidney vetch, 85; chickweed, 85; sweet clover, 85; black-seeded plantain, 85; mallow, 85; spurry, 85; stick-tight, 85; blue field madder, 85; other weed seeds, 2,635.

Total weed seeds to the pound, 64,940.

Sample No. 3816.—Buckhorn, 13,104; clover dodder, 6,240; wild carrot, 5,304; sorrel, 4,914; healall, 4,758; yellow trefoil, 2,574; lamb's-quarters, 1,170; green foxtail, 546; kidney vetch, 468; low hop-clover, 312; round-leaf toad flax, 234; curled dock, 234; lesser starwort, 234; chickweed, 78; ox-tongue, 156; black-seeded plantain, 156; plantain, 78; forget-me-not, 78; wood rush, 78; small crab-grass, 78; bull thistle, 78; bird's-foot trefoil, 78; other weed seeds, 3,900.

Total weed seeds to the pound, 44,850.

Sample No. 3834.—Clover dodder, 7,055; field dodder, 680; buckhorn, 7,820; sorrel, 6,205; healall, 4,420; wild carrot, 2,975; lamb's-quarters, 2,125; yellow trefoil, 1,190; green foxtail, 425; curled dock, 255; rabbit's-foot clover, 170; bird's-foot trefoil, 170; small-flowered crane's-bill, 170; chickweed, 170; yellow foxtail, 85; black-seeded plantain, 85; ox-tongue, 85; forget-me-not, 85; other weed seeds, 3,145.

Total weed seeds to the pound, 37,315.

Sample No. 3906.—Buckhorn, 14,305; clover dodder, 28,475; sorrel, 6,375; wild carrot, 6,375; healall, 6,375; lamb's-quarters, 3,145; yellow trefoil, 3,060; green fox-

tail, 2,295; black-seeded plantain, 1,275; low hop-clover, 935; rabbit's-foot clover, 850; red pimpernel, 680; curled dock, 680; mayweed, 425; bird's-foot trefoil, 340; kidney vetch, 340; hop-clover, 255; witch-grass, 170; ox-tongue, 170; lesser starwort, 170; round-leaved toad flax, 170; small-flowered crane's-bill, 85; ragweed, 85; spurry, 85; small crab-grass, 85; lady's-thumb, 85; sweet clover, 85; nipplewort, 85; other weed seeds, 4,845.

Total weed seeds to the pound, 82,305.

Sample No. 3945.—Buckhorn, 22,050; clover dodder, 6,570; healall, 3,960; green foxtail, 2,430; wild carrot, 2,430; lamb's-quarters, 2,340; yellow trefoil, 1,980; sorrel, 1,350; bird's-foot trefoil, 540; red pimpernel, 540; ox-tongue, 90; vervain, 270; small crab-grass, 180; low hop-clover, 90; lady's-thumb, 90; slender paspalum, 90; curled dock, 90; wild chicory, 90; field camomile, 90; hawkweed picris, 90; mayweed, 90; hop-clover, 90; other weed seeds, 2,430.

Total weed seeds to the pound, 47,970.

Sample No. 3946.—Buckhorn, 14,400; yellow trefoil, 3,570; healall, 1,615; clover dodder, 1,445; kidney vetch, 935; green foxtail, 850; lamb's-quarters, 1,020; sorrel, 850; wild carrot, 255; rabbit's-foot clover, 170; bird's-foot trefoil, 170; round-leaved toad flax, 85; ox-tongue, 85; bur clover, 85; small-flowered crane's-bill, 85; other weed seeds, 1,020.

Total weed seeds to the pound, 26,640.

Sample No. 3959.—Sorrel, 680; lamb's-quarters, 425; sweet clover, 425; green foxtail, 85; wild carrot, 85; yellow trefoil, 85; dodder, 85; lesser starwort, 85; rabbit's-foot clover, 85; other weed seeds, 595.

Total weed seeds to the pound, 2,635.

Sample No. 3960.—Buckhorn, 1,700; lamb's-quarters, 1,190; clover dodder, 850; yellow trefoil, 595; low hop-clover, 510; wild carrot, 340; green foxtail, 340; yellow foxtail, 255; blueweed, 170; rabbit's-foot clover, 170; sorrel, 170; healall, 85; sweet clover, 85; field camomile, 85; scentless camomile, 85; small-seeded false flax, 85; other weed seeds, 425.

Total weed seeds to the pound, 7,140.

Sample No. 3962.—Dodder, 1,190; buckhorn, 425; lamb's-quarters, 255; sweet clover, 510; low hop-clover, 85; curled dock, 85; yellow trefoil, 85; blueweed, 85; kidney vetch, 85; other weed seeds, 510.

Total weed seeds to the pound, 3,315.

Sample No. 3963.—Buckhorn, 2,028; wild carrot, 546; sorrel, 390; clover dodder, 936; field camomile, 156; yellow foxtail, 78; wild chicory, 78; healall, 78; lamb's-quarters, 390; other weed seeds, 702.

Total weed seeds to the pound, 5,382.

Sample No. 3964.—Buckhorn, 3,690; sorrel, 1,722; clover dodder, 1,066; lamb's-quarters, 246; lesser starwort, 82; yellow foxtail, 82; healall, 82; forget-me-not, 82; other weed seeds, 574.

Total weed seeds to the pound, 7,626.

Sample No. 3965.—Low hop-clover, 170; lamb's-quarters, 170; buckhorn, 85; healall, 85; wild carrot, 85; forget-me-not, 85; blueweed, 85; dodder, 85; chickweed, 85.

Total weed seeds to the pound, 935.

Sample No. 3967.—Lamb's-quarters, 1,615; buckhorn, 1,020; dodder, 850; yellow trefoil, 340; wild carrot, 255; sweet clover, 170; rabbit's-foot clover, 170; forget-me-not, 85; red pimpernel, 85; field camomile, 85; sorrel, 85; other weed seeds, 850.

Total weed seeds to the pound, 5,610.

Sample No. 3990.—Green foxtail, 20,060; curled dock, 4,590; bitter dock, 170; lamb's-quarters, 5,440; buckhorn, 680; yellow trefoil, 850; lady's-thumb, 425; stick-tight, 255; sorrel, 170; mayweed, 170; Canada thistle, 170; ragweed, 170; barnyard grass, 85; other weed seeds, 850.

Total weed seeds to the pound, 34,085.

Sample No. 3994.—Plantain, 26,814; mouse-ear chickweed, 12,300; five-finger, 3,608; buckhorn, 2,788; lamb's-quarters, 3,115; sorrel, 2,378; curled dock, 2,132; shepherd's-purse, 1,804; black-seeded plantain, 1,722; mayweed, 1,722; small crab-grass, 738; yellow trefoil, 656; lady's-thumb, 492; stick-tight, 410; witch-grass, 410; wormseed mustard, 328; peppergrass, 328; barnyard grass, 246; yellow foxtail, 82; evening primrose, 82; spiny sow thistle, 82; sedge, 82; catmint, 82; clover dodder, 82; knotweed, 82; three-seeded mercury, 82; green foxtail, 5,740; Canada thistle, 904; small-seeded false flax, 82; clover dodder, 82; other weed seeds, 4,018.

Total weed seeds to the pound, 73,473.

Sample No. 4009.—Buckhorn, 12,948; wild chicory, 1,968; yellow trefoil, 2,460; wild carrot, 1,640; hop-clover, 82; rabbit's-foot clover, 82; clover dodder, 820; Chilean clover dodder, 164; green foxtail, 984; yellow foxtail, 246; healall, 820; saltbush, 738; lamb's-quarters, 656; kidney vetch, 492; black-seeded plantain, 82; bracted plantain, 82; plantain, 82; barnyard grass, 328; sorrel, 410; curled dock, 328; knotweed, 246; field camomile, 246; mayweed, 82; sweet clover, 164; ragweed, 164; red pimpernel, 164; Canada thistle, 82; cut-leaved crane's-bill, 82; bird's-foot trefoil, 82; nippelwort, 82; sticktight, 82; other weed seeds, 2,788.

Total weed seeds to the pound, 29,676.

Sample No. 4010.—Buckhorn, 23,375; sorrel, 11,730; clover dodder, 11,815; healall, 6,460; yellow trefoil, 4,675; lamb's-quarters, 2,465; wild carrot, 1,105; red pimpernel, 1,190; low hop-clover, 1,105; rabbit's-foot clover, 1,105; mouse-ear chickweed, 1,360; lesser starwort, 935; hop-clover, 935; vervain, 850; chickweed, 255; spurry, 255; kidney vetch, 255; green foxtail, 255; mayweed, 170; field camomile, 85; forget-me-not, 85; small-flowered crane's-bill, 85; bur clover, 85; black-seeded plantain, 85; plantain, 85; other weed seeds, 8,330.

Total weed seeds to the pound, 79,135.

Sample No. 4026.—Buckhorn, 60,210; green foxtail, 6,390; ox-tongue, 6,930; wild carrot, 5,950; clover dodder, 3,570; yellow trefoil, 3,315; red pimpernel, 2,040; healall, 1,955; bird's-foot trefoil, 1,785; ox-tongue, 1,445; round-leaved toad flax, 1,190; wild chicory, 340; hawkweed picris, 255; mayweed, 85; other weed seeds, 1,275.

Total weed seeds to the pound 96,735.

Sample No. 4029.—Yellow trefoil, 5,220; buckhorn, 1,615; sorrel, 1,360; lamb's-quarters, 595; healall, 85; yellow foxtail, 85; other weed seeds, 510.

Total weed seeds to the pound, 9,470.

Sample No. 4031.—Clover dodder, 11,730; sorrel, 765; lamb's-quarters, 680; wild carrot, 595; healall, 510; black-seeded plantain, 255; buckhorn, 255; curled dock, 85; five-finger, 85; other weed seeds, 170.

Total weed seeds to the pound, 15,130.

Sample No. 4032.—Lamb's-quarters, 20,418; lady's-thumb, 410; cleavers, 656; curled dock, 410; saltbush, 246; stick-tight, 246; small-seeded false flax, 164; yellow trefoil, 164; sorrel, 82; other weed seeds, 574.

Total weed seeds to the pound, 23,370.

Sample No. 4035.—Lamb's-quarters, 5,304; buckhorn, 936; clover dodder, 780; sorrel, 546; rabbit's-foot clover, 156; yellow trefoil, 234; wild carrot, 156; blueweed, 156; green foxtail, 78; spurry, 78; bird's-foot trefoil, 78; other weed seeds, 3,822.

Total weed seeds to the pound, 12,324.

Sample No. 4038.—Clover dodder, 1,170; lamb's-quarters, 2,880; wild carrot, 360; scentless camomile, 270; wild chicory, 180; mayweed, 90; healall, 90; red pimpernel, 90; plantain, 90; sorrel, 90; hop-clover, 90; other weed seeds, 540.

Total weed seeds to the pound, 5,940.

Sample No. 4044.—Buckhorn, 12,710; clover dodder, 18,204; wild carrot, 6,630; sorrel, 2,865; healall, 3,910; yellow trefoil, 3,230; lamb's-quarters, 2,465; green foxtail, 1,615; curled dock, 1,530; round-leaved toad flax, 1,105; red pimpernel, 1,020; black-seeded plantain, 680; hop-clover, 595; low hop-clover, 510; spurry, 340; lesser star-

wort, 340; mayweed, 255; field camomile, 170; small crab-grass, 170; kidney vetch, 255; yellow foxtail, 85, stick-tight, 85; wild chicory, 85; lady's-thumb, 85; ox-tongue, 85; chickweed, 85; other weed seeds, 5,100.

Total weed seeds to the pound, 64,209.

Sample No. 4051.—Sorrel, 2,720; lamb's-quarters, 340; rabbit's-foot clover, 340; black-seeded plantain, 255; knotweed, 85.

Total weed seeds to the pound, 3,740.

Sample No. 4058.—Low hop-clover, 85; buckhorn, 170; field camomile, 170; clover dodder, 85; healall, 85; other weed seeds, 425.

Total weed seeds to the pound, 1,020.

Sample No. 4067.—Buckhorn, 15,030; green foxtail, 8,100; black-seeded plantain, 7,650; barnyard grass, 630; yellow foxtail, 540; three-seeded mercury, 540; knotweed, 270; lady's-thumb, 270; plantain, 270; five-finger, 180; yellow trefoil, 90; lamb's-quarters, 90; curled dock, 90; witch-grass, 90; other weed seeds, 360.

Total weed seeds to the pound, 34,200.

Sample No. 4084.—Lady's-thumb, 10,030; plantain, 20,740; mouse-ear chickweed, 17,000; curled dock, 3,230; shepherd's-purse, 2,975; yellow trefoil, 1,785; lamb's-quarters, 1,700; five-finger, 1,615; green foxtail, 935; black-seeded plantain, 850; Canada thistle, 680; spiny sow thistle, 255; yellow foxtail, 170; knotweed, 85; other weed seeds, 340.

Total weed seeds to the pound, 62,390.

Sample No. 4097.—Buckhorn, 16,405; clover dodder, 24,820; wild carrot, 6,290; sorrel, 6,205; healall, 6,035; yellow trefoil, 3,910; green foxtail, 3,485; lamb's-quarters, 3,400; kidney vetch, 1,020; vervain, 935; red pimpernel, 850; black-seeded plantain, 595; low hop-clover, 510; mayweed, 510; curled dock, 510; rabbit's-foot clover, 425; lesser starwort, 240; ox-tongue, 255; saltbush, 255; field camomile, 170; wild chicory, 170; lady's-thumb, 170; small crab-grass, 170; blue field madder, 85; slender paspalum 85; ragweed, 85; small-flowered crane's-bill, 85; hedge mustard, 85; hop-clover, 85; sweet clover, 85; other weed seeds, 7,395.

Total weed seeds to the pound, 85,325.

Sample No. 4118.—Yellow trefoil, 20,790; buckhorn, 20,610; healall, 3,510; wild carrot, 3,150; clover dodder, 2,970; sorrel, 2,160; catchfly, 1,080; lamb's-quarters, 990; field camomile, 900; red pimpernel, 540; kidney vetch, 270; green foxtail, 180; scentless camomile, 180; chickweed, 180; small-flowered crane's-bill, 180; Canada thistle, 90; wild chicory, 90; lady's-thumb, 90; lesser starwort, 90; cut-leaved crane's-bill, 90; blue field madder, 90; field dodder, 90; other weed seeds, 1,980.

Total weed seeds to the pound, 60,300.

Sample No. 4163.—Buckhorn, 4,410; plantain, 3,825; green foxtail, 3,655; mayweed, 1,870; black-seeded plantain, 1,530; curled dock, 765; five-finger, 425; catmint, 340; sorrel, 340; lady's-thumb, 340; Canada thistle, 340; ragweed, 255; mouse-ear chickweed, 170; barnyard grass, 170; yellow trefoil, 170; wild basil, 170; yellow foxtail, 85; wormseed mustard, 85; small crab-grass, 85; other weed seeds, 2,635.

Total weed seeds to the pound, 21,665.

Sample No. 4165.—Black-seeded plantain, 93,585; green foxtail, 6,035; small crab-grass, 7,055; crab-grass, 4,760; witch-grass, 4,845; buckhorn, 2,720; curled dock, 2,380; lady's-thumb, 1,785; pennyroyal, 1,445; lamb's-quarters, 1,360; bracted plantain, 1,445; spurge, 1,275; yellow foxtail, 1,105; spreading panicum, 595; sorrel, 850; pepper-grass, 340; evening primrose, 255; mayweed, 255; yellow trefoil, 255; slender paspalum, 170; barnyard grass, 170; spiny sida, 170; wild carrot, 170; catmint, 85; three-seeded mercury, 85; other weed seeds, 4,080.

Total weed seeds to the pound, 137,275.

Sample No. 4179.—Buckhorn, 20,202; clover dodder, 35,802; wild carrot, 5,772; lamb's-quarters, 5,070; sorrel, 5,070; yellow trefoil, 2,886; healall, 3,822; low hop-clover, 1,092; green foxtail, 1,014; red pimpernel, 624; dodder, 468; vervain, 546;

rabbit's-foot clover, 468; oxtongue, 390; hop-clover, 312; curled dock, 234; saltbush, 234; field camomile, 234; mayweed, 156; wild chicory, 156; black-seeded plantain, 156; nettle-leaved goosefoot, 78; forget-me-not, 78; mouse-ear chickweed, 78; lady's-thumb, 78; scentless camomile, 312; plantain, 78; chickweed, 78; lesser starwort, 234; kidney vetch, 78; other weed seeds, 3,822.

Total weed seeds to the pound, 91,422.

Sample No. 4180.—Buckhorn, 27,716; clover dodder, 35,670; low hop-clover, 1,445; rabbit's-foot clover, 255; wild carrot, 3,400; sorrel, 3,485; yellow trefoil, 3,145; healall, 2,890; lamb's-quarters, 2,720; field camomile, 765; red pimpernel, 595; green foxtail, 510; wild chicory, 425; lesser starwort, 340; chickweed, 85; nipplewort, 85; Canada thistle, 85; forget-me-not, 85; small-flowered crane's-bill, 85; bird's-foot trefoil, 85; small-seeded false flax, 85; other weed seeds, 3,145.

Total weed seeds to the pound, 77,101.

Sample No. 4181.—Buckhorn, 21,690; clover dodder, 46,980; sorrel, 7,565; wild carrot, 5,780; lamb's-quarters, 4,760; healall, 4,335; yellow trefoil, 2,465; green foxtail, 1,360; lesser starwort, 935; red pimpernel, 850; scentless camomile, 765; low hop-clover, 765; round-leaved toad flax, 595; rabbit's-foot clover, 510; black-seeded plantain, 595; field camomile, 340; kidney vetch, 340; wild chicory, 340; spurry, 255; chickweed, 170; ox-tongue, 170; forget-me-not, 170; saltbush, 170; hop-clover, 170; ox-eye daisy, 170; yarrow, 85; plantain, 85; mayweed, 85; curled dock, 85; other weed seeds, 5,440.

Total weed seeds to the pound, 90,025.

Sample No. 4183.—Buckhorn, 9,540; clover dodder, 8,460; lamb's-quarters, 6,210; green foxtail, 4,320; oxtongue, 1,710; round-leaved toad flax, 1,800; yellow trefoil, 1,260; red pimpernel, 900; low hop-clover, 810; wild carrot, 540; sorrel, 360; hawkweed picris, 360; healall, 180; large-seeded false flax, 180; mayweed, 180; forget-me-not, 180; rabbit's-foot clover, 90; spurry, 90; witch grass, 90; field camomile, 90; small-seeded false flax, 90; field cress, 90; horehound, 90; Frenchweed, 90; bull thistle, 90; other weed seeds, 3,510.

Total weed seeds to the pound, 41,310.

Sample No. 4225.—Buckhorn, 26,910; Chilean dodder, 5,940; wild carrot, 9,360; sorrel, 7,560; catchfly, 7,380; healall, 6,390; clover dodder, 6,210; lamb's-quarters, 3,600; yellow trefoil, 2,610; small-flowered crane's-bill, 900; lesser starwort, 810; red pimpernel, 630; green foxtail, 630; spurry, 540; mayweed, 540; small crab-grass, 450; kidney vetch, 360; bird's-foot trefoil, 270; plantain, 270; blue field madder, 180; forget-me-not, 180; yellow foxtail, 180; oxeye daisy, 90; scentless camomile, 90; curled dock, 90; spurge, 90; slender paspalum, 90; chickweed, 90; hop clover, 90; low hop-clover, 90; other weed seeds, 5,760.

Total weed seeds to the pound, 88,380.

In Table II are given the analyses of the five samples of high-grade red clover offered for sale at an average price of $15.05 per hundred pounds, previously referred to.

TABLE II.—*Analyses of five samples of high-grade red clover seed offered for sale during the year ended June 30, 1906.*

Number of seed sample.	Red clover seed.	Other seeds.	Dirt and broken seed.	Dodder present.	Kinds of weed seeds.	Weight of 1,000 red clover seeds.	Germination of red clover seed.	Price per 100 pounds at which seed was offered for sale.	Live red clover seed (seed that germinated) in sample.	Actual cost of 100 pounds of red clover seed that germinated.
	Per cent.	*Per cent.*	*Per cent.*		*Number.*	*Milligrams.*	*Per cent.*		*Per cent.*	
36668	96.59	1.44	1.97	No	7	1,705	100	$15.00	96.59	$15.53
37427	98.54	.28	1.18	No	2	1,501	98.5	14.00	97.06	14.42
37440	98.42	.93	.65	No	7	1,531	97.5	14.75	95.96	15.37
37442	97.00	1.27	1.73	No	7	1,678	100	16.00	97.00	16.49
37443	98.10	.35	1.55	No	3	1,486	98	15.50	96.14	16.12
Average	97.73	.85	1.42	....	5.2	1,580	98.8	15.05	96.55	15.58

The accompanying diagram presents in graphic form a comparison of the averages of the analyses of red clover seed imported, as shown in Tables I and II.

ALFALFA.

Table III gives the analyses of sixteen selected low-grade samples of imported alfalfa seed, representing cargoes amounting to 275,572 pounds. Since the total importations of alfalfa seed during the same period were 5,688,689 pounds, the low-grade seed furnished about one-twentieth of the total. The quality of this low-grade seed is similar to that of the red clover seed shown in Table I. The germination is low and the seed in many samples is small or shriveled. All but two of these lots contain dodder, and all contained on an average more than fifteen kinds of weed seeds.

TABLE III.—*Analyses of sixteen samples of low-grade alfalfa seed imported during the fiscal year ended June 30, 1906.*

Number of seed sample.	Alfalfa seed.	Other seeds.	Dirt and broken seed.	Dodder present.[a]	Kinds of weed seeds.	Weight of 1,000 alfalfa seeds.	Germination of alfalfa seed.	Quantity of seed imported.[b]	Price per 100 pounds at which seed was imported.	Live alfalfa seed (seed that germinated) in sample.	Actual cost of 100 pounds of alfalfa seed that germinated.
	Per cent.	*Per cent.*	*Per cent.*		*Number.*	*Milligrams.*	*Per cent.*	*Pounds*		*Per cent.*	
2929	84.56	3.52	11.92	Yes	18	1,704	79.5	10,208	$9.50	67.22	$14.13
2941	96.18	1.28	2.54	No	1	2,166	46	12,106	8.10	44.24	18.30
2942	88.58	1.98	9.44	Yes	14	1,890	53	7,797	7.90	46.95	16.83
2996	89.42	3.68	6.9	No	10	1,787	56.5	16,475	9.25	50.52	18.31
3002	88.06	3.24	8.7	No	12	1,866	52.5	32,439	9.40	46.23	20.33
3003	87.8	3.54	8.66	No	12	1,748	45	15,923	9.90	39.5	25.06
3047	90.46	3.97	5.57	Yes	14	1,757	58	16,610	10.25	52.47	19.53
3068	94.38	2.59	3.03	Yes	9	1,834	50	14,475	8.50	47.19	18.01
3082	91.01	4.33	4.66	Yes	15	1,622	63.5	16,632	10.25	57.79	17.73
3158	90.8	4.68	4.52	Yes	18	1,328	9	33,275	2.00	8.17	22.22
3393	94.63	1.77	3.6	Yes	17	1,753	73.5	16,500	10.13	69.55	14.56
3751	87.4	2.1	10.5	Yes	20	1,529	8	33,022	2.63	6.99	37.55
4132	82.02	6.18	11.8	Yes	23	1,032	77	5,610	7.50	63.15	11.87
4135	72.54	14.13	13.33	Yes	22	1,065	50	11,396	6.00	36.27	16.54
4232	63.85	16.79	19.36	Yes	26	1,037	58.5	3,844	5.00	37.35	13.39
4267	81.31	4.38	14.31	Yes	21	1,164	43.5	29,261	5.70	35.37	16.12
Average	86.44	4.89	8.68	......	15.75	1,580	51.47	....	7.63	44.31	18.78

[a] 75 per cent of the samples contained dodder.
[b] Total quantity of low-grade alfalfa seed imported, 275,572 pounds.

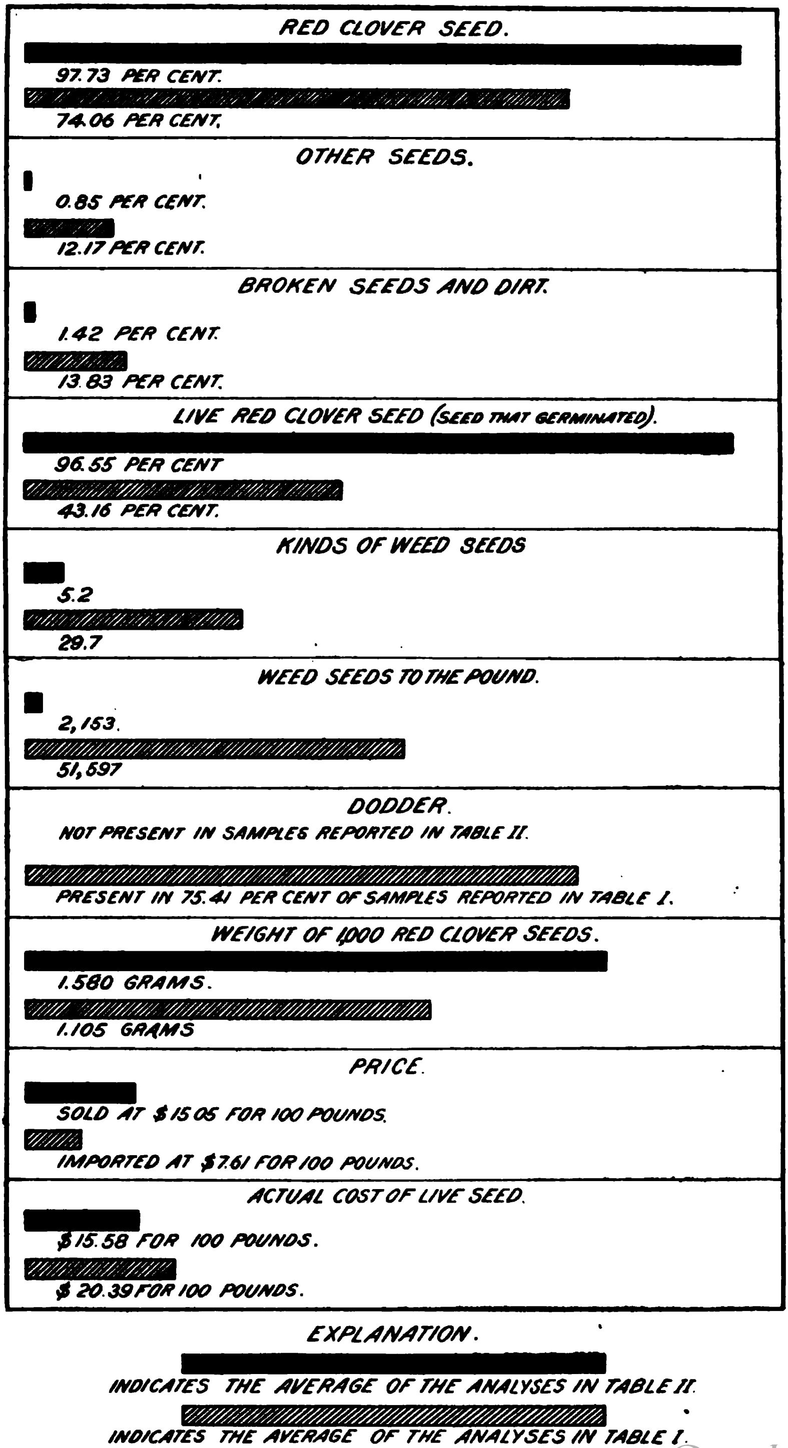


FIG. 4.—High-grade red clover seed compared with low-grade red clover seed: Averages of analyses shown in Table II (high-grade) and Table I (low-grade).

THE IMPORTATION OF LOW-GRADE SEED SHOULD BE STOPPED.

Every pound of worthless seed imported is finally sold to the farmer. Some of it goes into the trade to fill the demand for cheap seed. More of it is used to mix with better seed in the grading-down process. By mixing 100 pounds of seed worth $15 with 100 pounds of imported screenings which cost $7.50, a medium grade will result, costing $11.25 per hundred pounds, which is not sold at $11.25 but at $13 or $14 per hundred pounds. Whenever a dealer mixes two qualities of seed together to make a medium or low grade the price is not reduced in proportion to the quality. In this way the jobber or dealer who mixes seeds invariably gets a profit on the screenings which are used.

Unfortunately many farmers in the United States furnish a ready market for the refuse from our own cleaning mills, and moreover, on account of their demand for cheap seed, we are importing the waste from other countries. Seedsmen should not, perhaps, be altogether blamed for meeting this demand for cheap seed, and they must be expected to sell it as long as there is a call for it. At the same time, the farmer not being as good a judge as the seedsman often takes what is offered at the lowest price and unwittingly pays more for the seed that will grow than if he had bought the best. What is of more importance to the farmer, however, is not that he is paying more for his seed than he should, but that in buying low-grade seed he gets either a poor stand from sowing dead seed, or small, weak plants from sowing seed of low vigor, or the crop is smothered by weeds which will continue to foul the land for many years.

Argentina has a law prohibiting the importation of alfalfa and clover seed containing the seed of dodder. Canada prohibits the sale within her borders of seed containing weed seeds, but provides for its export. Europe is effectually protected from the use of poor seeds through its seed-control stations, but its screenings are exported. It seems time that the United States had some restriction on the importation of seeds of such poor quality that they can not be sold in other countries.

B. P. I.—317.

FORAGE CROPS FOR HOGS IN KANSAS AND OKLAHOMA.

By C. E. Quinn, *Scientific Assistant, Farm Management Investigations.*

INTRODUCTION.

Farmers are more and more realizing that pasture is necessary for the most economical production of pork. Those who are raising hogs and putting them on the market with the least cost have their entire farms fenced hog tight. This enables them to give the hogs the range of the meadows and fields when the crops have been harvested. Much that would otherwise be lost is thus saved by the hogs, for they are among the best gleaners of the waste grain, weeds, and insects in the fields.

More hog pastures are fenced each year, more experimenting is being done, and there is more inquiry as to the best crops for pasture. These questions can not be answered intelligently without a knowledge of the conditions of soil and climate, the market, and the adaptability of crops to different sections of the country.

The Office of Farm Management Investigations has undertaken to ascertain by a study of farm practice: (1) What crops have been found best for pasture for hogs in different localities; (2) the season during which these crops are available; (3) the number of stock they will pasture to the acre; (4) the value of this pasture in connection with other feeds; (5) the quantity of grain necessary to produce a given amount of pork on different pastures; and (6) the cost of producing pork.

While only a small beginning has been made, the demand for such knowledge and its importance to the swine industry of the country has prompted the publishing of this information for each locality as it is obtained.

CROPS USED IN KANSAS AND OKLAHOMA.

During the past summer (1907) about 150 of the most successful swine growers and pork producers of Kansas and Oklahoma were interviewed on the subject of the crops used for feed. In southern

Oklahoma along the river valleys and in northern Oklahoma and southern Kansas the farmers are favored with a soil and climate that make it possible to produce pork very cheaply. The mildness of the climate makes it unnecessary to build as expensive shelters for hogs in winter as are required farther north, and the open and short winters make it possible to furnish pasture during a greater portion of the year, thus lessening the amount of grain which it is necessary to feed. The main pasture crops for hogs in this region are alfalfa, wheat, oats, and rye, ranking in importance in the order named.

ALFALFA.

It is the testimony of 95 per cent of the farmers interviewed in this region that there is no better pasture for hogs than alfalfa, where it can be grown successfully. Those who have failed with it as pasture owe their failure to two causes. First, the alfalfa has been pastured before it has become well rooted. Young alfalfa is too tender a plant to stand severe treatment except under very favorable circumstances. There are a few farmers who have pastured it the same year it was sown and the alfalfa has survived, but this was on rich, heavy loam soil, usually creek bottom or river valley land with water not far below the surface, and the season was very favorable. Ordinarily alfalfa should not be pastured until the second year, and better still not until the third year if it is desired to keep the field as permanent pasture.

The second cause of failure with alfalfa is heavy pasturing and lack of judgment in pasturing in unfavorable seasons. A good many farmers have sown a small piece of alfalfa, and then because it has grown rapidly and all kinds of stock are fond of it they have turned all the stock on the farm on it and have wondered why their alfalfa was killed out. Others pasture regardless of whether the ground is muddy or whether the season is dry and hot. In either case heavy pasturing is very likely to cause the alfalfa to be killed out.

ALFALFA PASTURES.

As to the amount of pasturage or the number of hogs alfalfa will carry per acre without injury to the crop, the estimates given by farmers vary considerably, depending on the kind of soil, the fertility of the land, and the size of the hogs pastured. The following, however, is a safe average estimate as given by conservative men who have had much experience. River valley and creek bottom land well set in alfalfa will carry from 15 to 20 head per acre of 50 to 125

pound hogs. Upland of fair average fertility will support from 8 to 10 head of the same kind of hogs. There are fields that have supported 25 head per acre all through the season for a number of years and are still in good condition, and there are other fields that will not furnish pasture for more than 5 head per acre; but these are extremes. When a field is used only for pasture it is better to divide it into several lots and move the hogs from one to the other as occasion requires.

The length of the season during which this pasture is furnished also varies. Alfalfa is ready for pasture on the average from the middle of April in southern Oklahoma to the middle of May in northern Kansas. In many cases it will do to pasture earlier, but it is not best, as the young alfalfa has not the start it should have for heavy pasturing, nor has it the strength in the plant. When not pastured too early it will furnish feed at the rate mentioned during nearly the whole season until October in the North and November in the South. In some years the pasture season will continue a month later in the autumn, depending on the rainfall and the lateness of cool weather. In some seasons, if the summer is unusually dry and hot, the pasture will become short; but usually pasture for the number of hogs previously specified can be depended on for about seven months of the year in the southern limit of the territory named and for about five months in the northern limit. This rule will apply to other sections of the country in the same latitude as Oklahoma and Kansas.

While many farmers pasture alfalfa fields to their full capacity, in some sections, especially in northern Kansas, it is customary to run about half as many hogs as the alfalfa fields will support. This practice permits the cutting of the usual number of crops of hay, though the yield of hay is, of course, reduced.

Alfalfa not only furnishes a great amount of pasture, but it is of a character that goes to make bone and muscle. It belongs to the leguminous family of plants, as do the clovers, the cowpea, the field pea, the soy bean, and the vetches, and while it is furnishing this valuable food it is at the same time adding fertility to the land. Alfalfa pasture or alfalfa hay and corn are very nearly a balanced ration for animals, and while it is better to have a grain ration fed with it to hogs as well as other animals, yet a healthier, thriftier hog can be raised on alfalfa alone than on corn alone. Many instances are found where hogs have been raised on alfalfa alone. One Oklahoma farmer marketed in December, 1905, 61 head of spring pigs eight months old that averaged 171 pounds. These hogs had run from the time they were little pigs with their mothers on 15 acres of

alfalfa without any grain. They sold on the market for 5½ cents a pound. This made the cash value of the alfalfa pasture about $38.35 per acre. As will be seen, this is light pasturing, as there were only about 4 pigs per acre besides the brood sows.

As already stated, it is much better economy to furnish a grain ration with the pasture, as it results in better gains and a better product. One man estimates that it takes from one-half to one-third less corn on alfalfa pasture than on a straight grain ration to make a hog ready for market. Many let the hogs run on alfalfa until about five to six months old, by which time they reach a weight of 75 to 125 pounds, feeding just a little grain; then they feed heavily for about two months and sell the hogs at eight months old weighing 200 to 225 pounds. One farmer, who raises about a thousand hogs a year and who in one year sold $11,200 worth of hogs, makes a practice of growing his hogs on alfalfa pasture until about eight months old, feeding one ear of corn per head daily. He then feeds heavily on corn for a month or two and sells at an average weight of 200 to 225 pounds. Another man feeds all the corn and slop the pigs will clean up, all the while running them on alfalfa pasture, and sells at six to eight months old at weights of 250 to 300 pounds. Another, who raises about a thousand head a year, feeds all the corn the pigs will eat, beginning shortly after weaning and continuing until the hogs are sold at ten to eleven months old, averaging about 275 pounds.

Still another farmer, from weaning time (two months old) until eight months old, feeds the pigs nothing but dry corn on alfalfa pasture, averaging about one-half gallon of corn (3½ pounds) a day per head. At the end of eight months he sells at an average weight of 250 pounds. Feeding the above quantity of corn a day makes the amount fed about 11¼ bushels per head. Figuring this at the average price of corn in this locality, 35 cents, and the price received for pork, 5½ cents, the following results will show the cost of growing pork on this farm and the value of alfalfa pasture:

Value of 250-pound hog, at 5½ cents	$13.75
Value of pig at weaning, 50 pounds, at 5½ cents	2.75
Gain from pasture and grain	11.00
Cost of 11¼ bushels of corn, at 35 cents	3.93
Value of pasture per head pastured	7.07

Now, compare these results with those of a man who had to depend on other pasture crops than alfalfa. He estimates that it will take 15 bushels of corn on wheat, oats, and rye pasture to raise and fatten a hog so it will weigh 240 pounds at nine months old, besides the pasture and slop. At the price of corn mentioned, 35 cents a bushel,

and with hogs at 5½ cents a pound, note the cost of producing pork on this farm:

Value of 240-pound hog, at 5½ cents	$13.20
Value of pig at weaning, 50 pounds, at 5½ cents	2.75
Gain from pasture and grain	10.45
Cost of 15 bushels of corn, at 35 cents	5.25
Value of pasture per head pastured	5.20

The pasture specified here will not support more than half as many head per acre on this farm by feeding corn all the time. The value of this pasture is only $5.20 per head, against $7.07 per head for alfalfa pasture on the other farm.

The experiences of these men are sufficient to show the value of alfalfa pasture alone, and its greater value when grain is fed in connection, and that it is an important factor in economic pork production. A little later in this bulletin will be given the feeding systems of some farmers which will still further show the excellence of this forage crop and others and the cost of producing pork under such systems.

ALFALFA HAY.

While alfalfa pasture has been found to be very valuable for hogs, the hay as a part ration for winter is scarcely less important. Throughout the region referred to the farmers are feeding the hay to hogs in winter. Many feed the hay by throwing it on the ground in forkfuls; others have made low racks in which the hay is placed, where the hogs can feed like cattle or sheep. The hay has been found to be especially valuable for brood sows before farrowing. Where it is fed during the winter only a small grain ration is necessary to keep the sows in good flesh and in healthy condition. Sows thus fed also farrow good litters of strong, healthy pigs.

The hay is usually fed dry. The leaves are more readily eaten by the hogs than the stems, as they contain more of the nutritive value of the plant. For this reason some farmers save the last cutting of hay for the hogs because it is more relished. It is eaten up cleaner, as the stems are not so woody, and more food value is found in the leaves. Sometimes the hay is cut up fine, wet, and mixed with other feed, and sometimes it is fed ground, as there are now alfalfa mills scattered throughout the alfalfa regions. But it is very doubtful whether this extra expense will pay, unless it be for a ration for young pigs.

To avoid the expense of cutting or grinding, some farmers in order to get the hay all eaten have soaked it in water and fed it. This has proved very satisfactory where tried. One Oklahoma farmer carried his hogs through a winter by feeding them alfalfa leaves soaked in hot water for one day and the next day shorts mixed with the pulp and water. He feeds much alfalfa hay to his hogs and is very successful with them. He puts the last cutting in shock as soon as wilted, and thus cures it without bleaching and feeds it to his hogs. Another farmer carried his entire herd of hogs through the winter by feeding them the pulp of alfalfa hay after soaking it in water over night. He also gave them the water to drink. This was all the feed they had during the winter, and they were in good flesh in the spring, with smooth glossy coats of hair. A Kansas farmer was feeding a bunch of 50 fall pigs on corn; during the winter they got off feed and were not thrifty. He reduced the corn and gave a ration of two-thirds chopped alfalfa hay and one-third corn meal, the two soaked together. The hogs began to do better, and a little later he changed the ration to one-third alfalfa and two-thirds corn. The results were very satisfactory, and the cost of feed was reduced from $15 a month on corn to $9 a month on alfalfa and corn. So alfalfa hay, as well as pasture, has a very important use on a hog farm.

WHEAT.

In northern Oklahoma and southern Kansas fall wheat is a staple crop. It is generally seeded from the middle of September to the first of October. The seeding is usually $1\frac{1}{4}$ to $1\frac{1}{2}$ bushels per acre. If the ground has been well prepared and the fall is not too dry, this will have made a good growth by the time alfalfa pasture is beginning to fail, along in November. The season here usually remains open until Christmas, so that six weeks of very good pasture are furnished. Some winters are so open that the wheat remains green most of the winter and stock find pasture all winter. The spring opens up by the last of February and the wheat gets green again in March. By judicious pasturing, not pasturing too heavily or when the ground is muddy, much green feed may be had without injury to the wheat. The farmers here have taken advantage of this, and where they have their wheat fields fenced hog tight they turn the hogs from the alfalfa field to the wheat field in November and leave them there during the winter unless the wheat gets too short or the ground becomes muddy. The hogs remain in the wheat until April and do well with very little grain. At this time they can go back to the alfalfa field again. Thus, green pasture is furnished the year round.

Where this is possible two litters a year of 200-pound hogs can be raised with profit and pork produced very cheaply.

Wheat will not carry as many hogs to the acre as alfalfa. The usual number is about six head per acre, though some farmers claim that the maximum is about ten. One man claims that hogs are one of the best animals for pasturing on wheat, not trampling it out as cattle or horses do. Another farmer of large experience thinks it is dangerous to pasture pigs at about weaning time on wheat. He has lost twice, he thinks, from that cause. The last time he saved only 15 out of 45 head. He claims that wheat is too fibrous and collects in balls in a pig's stomach and intestines, causing inflammation, from which the pig dies. It is claimed by some farmers that wheat is injurious to hogs just as it begins to shoot in spring. More information is needed on this point. The usual practice is to remove the hogs from wheat in early spring and put them on alfalfa or other summer pasture, so that experience with wheat pasture later in the season is limited.

The value of wheat as pasture lies chiefly in the fact that it furnishes green feed for the hogs at a season of the year when it is very much needed, especially by young and growing hogs. By having pasture at this season there is a great saving of grain, very little being needed. It also enables fall pigs farrowed in September to be carried through the winter in good condition, thrifty and well grown, so that by giving corn in the spring they can be sent to market by June nearly as cheaply as the March pig can be shipped by December. Quite frequently, where hogs have been grown on alfalfa or wheat pasture, they will, when put on a heavy feed of corn, make a gain of 12 to 15 pounds for every bushel fed.

OATS.

In the same region where wheat is used for pasture, oats are also used for spring pasture and are highly spoken of by all who have used them. Some claim that hogs will do better on oats than on wheat. The hogs like them better and will eat them as long as they grow, while they do not like wheat when it begins to head. In this locality many sow oats in March to furnish spring pasture for the hogs when they come off the wheat and before the alfalfa is ready to pasture. Sometimes oats are sown with rape at this time for the same purpose and to give variety to the pasture. Oats will furnish pasture at about the same rate as wheat.

The great value of oats is due to the fact that they furnish succulent feed at a season when it is much needed, giving variety to the pasture. They are also greatly relished by hogs. Oats are particu-

larly valuable as pasture for sows and young pigs, many farmers sowing them for this purpose. One farmer claims that he is less troubled with scours in pigs on oat pasture than on alfalfa.

RYE.

Rye is not so generally grown for a pasture crop in Oklahoma and Kansas as the crops just discussed. Many farmers, however, use rye to make a part of the pasture crop for their hogs, and its value can not be denied.

Rye is seeded from September 1 to the middle of October. The early seeding is best, as it comes on early and gets well established before cold weather and will thus make better fall and winter pasture. Rye is an excellent pasture for late fall, winter, and early spring. If not pastured too heavily in the spring it will head out and make a very good yield of grain. The grain is an excellent ration to feed with corn to pigs and growing hogs or to grind and mix in slop for sows with pigs.

The amount of pasture furnished by rye is about three-fourths that furnished by alfalfa, being estimated as supporting from 6 to 12 hogs per acre. One man reports having pastured 50 head of hogs on 5 acres during fall, winter, and spring, then harvesting 20 bushels of grain per acre. In the southern part of this region rye would be an excellent cover crop for the soil during the winter. Besides furnishing pasture it could be turned under as a green manure to add humus to the soil.

LESS IMPORTANT FORAGE CROPS.

While alfalfa, wheat, oats, and rye are the principal forage crops, there are others that are used to some extent. Among these are clover, rape, sorghum, cowpeas, soy beans, artichokes, and grasses.

CLOVERS.

The clovers are not generally used in the territory discussed. Among those most used for pasture crops are red clover and white clover. These are good, especially in the latitude of central Kansas and farther north, but south of this the clovers do not do so well. Red clover and white clover are the older pasture crops and are in more general use in the older sections of the country. They are both excellent forage crops for hogs. Red clover comes in well in the rotation of crops; it fertilizes the land and furnishes both pasture and hay. It is often sown with oats or barley in the spring, or later in corn after the last cultivation. It does very well with corn

where there is sufficient rainfall, but in the drier regions this method of seeding clover is not to be recommended. The first fall it is used for pasture; the second season it is used as a pasture and hay crop. It will furnish pasture for about ten head of hogs per acre during the first half of the season and half that many the last half, provided the soil is fairly good and the season not too dry. The hay is excellent for hogs, especially for brood sows in winter, but does not equal alfalfa hay.

White clover is better used in permanent pasture with some of the grasses, as Kentucky bluegrass. It will not furnish as much pasture as red clover, but is especially good while in bloom during May and June. It does better on moist ground than red clover and will do very well on some poor soils. It is not recommended to sow alone nor for hay, although the dry hay contains upward of 14 per cent of crude protein.

Alsike clover is better in some regions than red clover, especially on low, moist ground. In some localities farther north it does better and is a more certain crop. It will supply about as much pasture as red clover, is seeded at the same time, and furnishes pasture for the same period. As a hay crop it will not yield as much, but it is a little better than red clover, as it does not have as woody a stem.

Crimson clover has not succeeded well in the past in this region, but is to be recommended for further trial as a pasture crop. Along the Atlantic coast, the only region where it is largely and successfully grown, it has been found that the hairs of the blossoms are likely to gather in dense balls in the stomach and intestines of animals, especially the horse, and cause death. For this reason it should not be cut for a hay crop after the flowers mature. It is an excellent winter pasture crop for swine, however, and will furnish more pasture than red clover. It is a winter annual, and should be sown in August or September.

The chief value of crimson clover is that it acts as an excellent cover crop for soil during the winter months and prevents the soil from washing or leaching. It also furnishes in southern regions excellent winter and early spring pasture for hogs.

RAPE.

Rape is usually sown in early spring—in March or early in April—in Oklahoma and furnishes pasture by May. The Dwarf Essex variety is used. It is seeded either broadcast, at about 4 pounds of seed per acre, or else in drills 30 to 32 inches apart, using 3 pounds per acre. Drilling is the best method, as this permits of cultivation. The plants grow more rapidly and make pasture sooner. When sown in drills,

the hogs will not break down and destroy so much of the crop. Early-sown rape will furnish pasture from May until August. If rape is not grazed too closely in the spring and the stalk is not eaten off, it will grow up and make fall pasture.

A good growth of rape will supply pasture for about 15 or 20 hogs to the acre. One man claims that it will take 25 head to pasture it down.

It is often difficult to get hogs to eat rape at first if they have not been accustomed to it. For this reason it is not grown by some. Its value as a forage crop, however, is shown in the experiments of the Wisconsin Agricultural Experiment Station, where it was proved to have a feeding value per acre, when combined with a ration of corn and shorts, equivalent to 2,436 pounds of grain and a money value of $19.49 per acre. When the cost of seeding is counted, rape proves valuable for pasture, as the seed can be bought usually for 8 cents a pound and 3 to 5 pounds an acre is all that is needed. Rape should not be pastured until it is a foot high.

Considerable complaint is found with rape because it causes sores and scabs on the hogs. Sometimes the skin has the appearance of being blistered. This is especially true of white hogs. This difficulty can be remedied somewhat by removing the hogs to other pasture crops for part of the time and applying a mixture of sulphur and lard to the sores.

As one of the annual forage crops rape is valuable on account of the cheapness of the pasture, the quantity of feed furnished, the general thriftiness of the hogs on the pasture, and because it adds variety to the ration and is available at a time when other pastures may be short.

SORGHUM.

Sorghum is used quite extensively in the drier upland regions for summer pasture. It is valuable on account of the great amount of feed furnished, pasturing from 20 to 30 head of hogs per acre. It comes in as a summer pasture when other pastures are frequently short on account of hot, dry weather. It is sown in May and furnishes pasture during July, August, and September, or even later.

Sorghum is less palatable and nutritious than many other forage crops adapted to this region. For this reason many do not like it as a pasture crop. Hogs do not thrive as well on it as on alfalfa and require more grain to keep them growing nicely.

The special value of sorghum lies in the fact that it furnishes a great abundance of pasture in dry, hot weather when alfalfa makes little growth. After it is well started, say 2 feet high, it will furnish fairly good pasture for 30 hogs to the acre for a few weeks, and

a good crop will carry 25 head of 100-pound pigs nearly all summer. Generally speaking, it is used only to fill in during dry, hot weather when alfalfa is at a standstill.

COWPEAS.

Cowpeas are just beginning to be recognized in this section as having great feeding and fertilizing value. They do much toward restoring the fertility of the soil, and some farmers are making use of the vines as a forage crop for their hogs. Wherever they have been tried the farmers are enthusiastic in their praise of them. Not enough data have been obtained on pasturing to be able to say how many head of hogs cowpeas will support per acre; but in a comparison of their feeding value with corn for hogs the results obtained by the South Carolina Experiment Station show their importance. In this test 6.02 pounds of corn and 4.91 pounds of cowpeas were necessary to produce a pound of pork. One farmer in Oklahoma reported that his hogs preferred the cowpea hay to alfalfa hay. All kinds of stock are fond of the hay and do well on it.

The value of cowpeas as a forage crop lies in the fact that they furnish a food on which the hogs make good gains. The plants will make a good growth on rather poor soil and furnish feed during late summer and fall when other green crops may be short. They also bring the soil into a more productive state, the same as clover or alfalfa.

If cowpeas are planted in May they will make late summer pasture. The best pasture is obtained after the peas are formed and well grown, as the peas are very nutritious and cause the hogs to gain in flesh rapidly.

In this same latitude in the higher altitudes, as in the San Luis Valley in southern Colorado, where it is too cold for corn, the farmers have found the Canadian field pea a very profitable crop for forage both for sheep and hogs. A large acreage of these peas is put in each year, the peas being sometimes sown alone, but more frequently with oats or barley. The seeding is done in April or early in May, and the crop can be pastured by midsummer. The best season for pasturing however, is later, when the peas have formed, the stock being allowed to harvest the crop. Hogs make a very thorough harvesting, cleaning up the peas and the vines quite thoroughly. What vines are left on the ground, together with the manure, enrich the soil and add more humus to it. In addition to this the labor of harvesting is saved. Some fields, of course, are harvested for hay and make excellent winter forage for cattle, horses, and sheep. The hogs raised in this valley receive no corn. They go on the market as bacon hogs and top the market in competition with corn-fed hogs. These hogs usually get no

farther than Pueblo, Leadville, Silverton, and adjoining towns. The Pueblo packers have been using them for a number of years and speak very highly of them. Thus, the field pea has made the hog industry profitable outside of the corn belt.

SOY BEANS.

The soy bean is used but little as a forage crop by farmers in this section, and the value of this crop is but little appreciated. Soy beans can be planted on a field from which a small grain crop has been removed, and some varieties will make an excellent growth of forage and even mature seed. They will thus furnish pasture for hogs during the latter part of August and September, and the green and ripening beans when harvested by the hogs in this way make an excellent feed. The beans when fed in a ration consisting of one part beans and three to five parts of corn or Kafir corn, as shown by the Kansas Agricultural Experiment Station, make a very profitable ration for fattening hogs. The saving in the amount of feed necessary to make a gain of 100 pounds is from 13.2 to 37.5 per cent and the increase in gain is from 14.6 to 96.4 per cent. Also, in a feeding test at the Indiana Agricultural Experiment Station, where soy beans, middlings, and tankage were used as rations with corn, the soy beans proved to be the most valuable adjunct used. As compared to corn fed alone, hogs that received one-third soy beans to two-thirds corn made two and one-fifth times as much gain in the same length of time. The cost per 100 pounds of gain where corn was fed alone was $5.01 against $3.59 where one-third soy beans and two-thirds corn was fed. Hogs so fed look thrifty, have a good appetite, fatten rapidly, and have glossy hair like animals fed oil meal.

The great value of the soy bean is its power to withstand excessive drought, like Kafir corn, and it will also withstand much wet weather. It is not attacked by chinch bugs and in addition to its great feeding value makes an excellent second crop following wheat or oats to build up run-down or thin soil. Protein is very necessary in a ration for building bone and muscle, as all feeders are coming to know, and the soy bean is exceptionally rich in this. It even stands ahead of alfalfa in this respect.

GRASSES.

The grasses are not so good for hog pasture as the crops previously mentioned, but they are used to some extent. Those most commonly grown are Kentucky bluegrass, English bluegrass or meadow fescue, Bermuda grass, and the native wild grasses.

Kentucky bluegrass is used through Kansas and southern Nebraska. South of Kansas in Oklahoma Bermuda grass is used.

As an example of the value of English bluegrass, the experience of one farmer in northern Oklahoma may be cited. He uses only English bluegrass and wild grass as pasture. On 12 acres of the bluegrass sown the fall before, he pastured 150 head of stock hogs all the spring until about the middle of May. The hogs were then taken off and the grass allowed to go to seed. This farmer states that he harvested a crop of seed larger than the ordinary crop.

Bermuda grass is not much used as a pasture for hogs, but should be grown more in regions to which it is adapted. It is relatively rich in protein, is not easily killed out by pasturing, and withstands drought well. It is often used as a soil binder and might well be used for hog pasture. Many hilly farms that are now washing badly could be put in Bermuda grass and pastured to stock, thus saving the land and building up the soil. Some farmers are beginning to make use of this grass and are fencing it for hog pasture. It withstands heavy grazing, rooting, and trampling.

Some farmers have fenced in the prairie grass and are now grazing their hogs on it. While it does not have a very high feeding value, hogs will do very well on it with grain. One man claims that prairie grass will make hogs hold their own at the rate of 6 head per acre.

ROOT CROPS.

The root crops most used in this territory are potatoes, artichokes, peanuts, and sugar beets.

Artichokes are a very good root crop to use for hogs. They can be planted in the spring the same way as potatoes and cultivated the same. In the fall the hogs can be turned in to harvest them. They thus furnish a good late fall and winter food, especially for brood sows and shoats. One farmer claims that 1 acre will keep from 20 to 30 head in fine condition from October till spring. Their use reduces considerably the amount of corn that must be fed. None of the tubers need be dug except for seed; the hogs will dig the rest. Early in the fall hogs do not eat artichokes readily. In winter and spring they eat them greedily.

Artichokes have a tendency to become a pest on cultivated land, or if planted continuously on the same land they become diseased. They may be grown very successfully, however, in a pasture crop rotation for hogs. As the acreage needed is not large, they can be planted on a part of a field in March or April and the rest of the field sown to rape. In August the part sown to rape can be reseeded to rape for fall pasture. This field can be sown to oats the next spring after rape, and barley sown after the artichokes. The crop may be pastured continuously if needed, or later mowed for hay. In August, after this crop is

removed, rye and clover may be sown. This will furnish pasture for the ensuing fall and for the following year. This makes a three-year rotation of pasture crops that fit in very well with each other. Preparing the land in July and August for the following crop of rye and clover effectually eradicates the artichokes.

The Oregon Agricultural Experiment Station made a test to determine the feeding value of artichokes with grain for hogs. The result of the test showed that where artichokes were fed there was a saving of nearly 2 pounds of grain for every pound of gain in live weight. Besides, the hogs were healthy and vigorous all the time.

The artichoke is superior to the common beets and turnips for hogs—about the same as potatoes—and they are richer in protein than sweet potatoes.

Peanuts are but little used in this region, but farther south and east they are used extensively. One man estimates that when pork is 4 cents a pound, peanuts return $10 per acre when harvested by hogs.

The Alabama Agricultural Experiment Station made investigations as to the relative value of peanuts, chufas, cowpeas, rape, sorghum, and sweet potatoes as pasture crops for hogs. The amount of grain required with peanuts to make 1 pound of gain was 1.77 pounds; with chufas, 2.3 pounds; with rape, 2.68 pounds; with cowpeas, 3.07 pounds; with sweet potatoes, 3.13 pounds, and with sorghum, 3.7 pounds. Five Tamworth hogs in twenty days on Spanish peanuts gained 2.29 pounds a day each.

Peanuts can be very profitably grown in many sections of the latitude of Oklahoma and Kansas. This crop will do better on a sandy loam than on a heavy clay soil, and will make a fair crop on thin soil where corn will not yield well. They are a very good crop to raise, both for pasture and for hay; stock of all kinds are very fond of the hay. When the nuts are left on, it is richer in protein than alfalfa hay. The variety best to grow, both for hay and pasture for hogs, is the Spanish peanut. It is a small-sized nut and grows in great clusters close around the taproot of the plant. The Spanish nut is not so particular in soil requirements as the larger varieties and is easier harvested on account of growing in clusters.

It is claimed that peanuts can be grown in dry regions where corn will not succeed. This, if true, is important in the southern-plains region. Peanuts can be made to take the place of corn in fattening hogs, although the peanut-fed hog makes softer lard and the quality of the meat is not so good, especially in the bacon hog. But as an adjunct to corn the peanut is an excellent forage crop. It is claimed that the northern-grown nut is better flavored and less oily than that grown in the South.

The peanut can be planted the last of April or first of May in the latitude of the regions discussed in these pages and is ready to turn the hogs on by the last of August.

In Colorado, in the sugar-beet district, hogs have been fed quite extensively on beets in the winter. Beets do not prove satisfactory when fed alone, but are used to some extent as part ration with grain. One farmer states that he saves a good supply each year to feed in the winter to his hogs to keep them in a healthy condition.

In a feeding test at the Colorado Agricultural Experiment Station sugar beets proved to be wholly unsatisfactory when fed with grain. The cost per hundred pounds of gain of beets and barley fed hogs was $6.01; of beets and corn fed hogs, $7.22, the latter being higher than any other ration fed.

PUMPKINS.

Pumpkins are an excellent feed for keeping hogs in a healthy condition. Many farmers claim that the seeds of pumpkins will prevent worms in pigs and shoats and that a ration of pumpkins fed with grain will keep hogs thrifty and give them a good appetite. A good many wagonloads can be grown on an acre of rich land. Stumpy land or low moist land will grow good pumpkins.

PASTURE CROPS FOR DIFFERENT SEASONS.

It is not the purpose of this bulletin to discuss the rotation of crops and its importance on the farm, but the aim is to briefly mention the forage crops that are adapted for hogs each month of the year in this region and to explain how they can be made to overlap each other, so that green pasture can be provided for each month in the southern part of the territory discussed and for the greater part of the year in the northern part. Hog raisers know that some months of the year there is an abundance of pasture, while at other seasons there is very little, if any. At such times other feeds must be resorted to that will supply the deficiency. The extra feed required is expensive and cuts down the margin of profit in pork production.

It will not be practicable to name the crop that is best adapted to every locality for the different seasons, as each farmer must know his soil and conditions and adapt his crops to those conditions. The following table will show the crops that may be ready for pasture in the months specified and the possible area of pasture provided, but the choice of one or more of these must be left to the farmer himself.

TABLE I.—*Crops that may be available for pasturing hogs every month in the year, with the number of head an acre will support.*[a]

For pasture during—	In the latitude of—	Crops that may be used.	Time of sowing.	Number of hogs that can be pastured per acre.
April and May	Oklahoma	Alfalfa	Previous year	8-16
		Rye	Previous fall	6-10
		Oats	March 1	6-10
		Rape	do	15-20
	Kansas	Alfalfa	Previous year	8-16
		Rye	Previous fall	6-10
		Clover	do	6-10
		Oats	Last of March	6-10
		Kentucky bluegrass.		8-10
		English bluegrass	Previous fall	8-12
June and July	Oklahoma	Spring rye	March 1	6-10
		Late oats	April 15	6-10
		Sorghum	March 1 to April 1	20-30
		Alfalfa	Previous year	8-16
		Potatoes	March	(Unknown.)
	Kansas	Rape	March 1 to April 15	15-20
		Spring rye	April 1 to 15	6-10
		Late oats	April 15 to May 1	6-10
		Sorghum	April 1	20-30
		Alfalfa	Previous year	8-16
		Prairie grass		5
August and September.	Oklahoma	Sorghum	April	20-30
		Cowpeas	May	10
		Soy beans	do	13
		Peanuts	April	8-10
		Alfalfa	Previous year	5-10
	Kansas	Sorghum	May 1	20-30
		Cowpeas	do	10
		Soy beans	do	10
		Peanuts	do	8-10
		Potatoes	April 1	(Unknown.)
		Alfalfa	Previous year	5-10
October and November	Oklahoma	Alfalfa	do	7-14
		Wheat	September 15	6-8
		Rye	September 1	7-10
		Sweet potatoes	May 1	8-12
		Artichokes	March or April	15-25
		Rape[b]	do	15-20
	Kansas	Alfalfa	Previous year	7-14
		Wheat	September 1	5-6
		Clover	March or April	6-10
		Peanuts	May 1	8-10
		Rye	September 1	5-6
		Sweet potatoes	May 1	8-10
		Artichokes	April	15-25
December and January	Oklahoma	Wheat	September 15 to October 1	5-8
		Rye	September	5-8
		Artichokes	April	15-25
	Kansas	Wheat	September 1	5-8
		Rye	do	5-8
		Artichokes[c]	April	15-25
February and March	Oklahoma	Wheat[d]	September 15 to October 1	5
		Rye	September	6-10
		Artichokes	April	15-25
	Kansas	Rye	September 1	5-10
		Artichokes[c]	April	15-25

[a] The number of hogs that can be pastured per acre, it must be remembered, depends on the fertility of the soil, on the season, and on the size of the hogs. This estimate is based on the same figures as were secured on alfalfa pasture; i. e., hogs that weigh from 50 to 125 pounds per head.

[b] Rape will furnish fall pasture as indicated if it is not pastured too close in the spring. It will branch out from the roots and stem in the fall. It may also be planted in August for fall pasture.

[c] Artichokes are available when not frozen. They may be left in the ground until it thaws in the spring, when the hogs will finish harvesting them.

[d] Wheat should not be pastured after the 1st of April if a crop of grain is desired.

SYSTEMS OF HOG FEEDING.

Nearly every farmer who has succeeded with hogs has a feeding system of his own, yet there are some features common to all. A good illustration of the successful handling of hogs on a small farm is that employed by a man in northern Oklahoma on an 80-acre farm. He has his whole farm fenced hog-tight and turns off annually from it an average of 100 head of hogs. All these are of his own raising and are grown and fitted for market with the crops raised on his farm, with the exception that a little corn is occasionally bought. He has 5 acres of alfalfa and each autumn sows 5 acres of wheat for late fall and winter pasture. In the spring he sows oats to supplement the wheat and alfalfa. The wheat is sown at the rate of 1½ bushels to the acre, about September 1, and furnishes pasture in the fall, when alfalfa pasture is getting short, and for a part of the winter. The wheat will also furnish some pasture for the hogs in the spring. The oats tide over until the alfalfa is ready for pasture. Thus, green feed is furnished for the greater part of the year. The rest of his 80 acres this farmer plants to corn. A part of this corn is fenced off and "hogged down" in the fall. As fast as the hogs need it the fence is moved over, and fresh corn is taken in. This pasturing is begun at the same time that corn is usually cut up green and fed to hogs, i. e., when it is in the roasting-ear stage. Spring pigs are turned on this. This plan of feeding is kept up until the remainder of the corn is all husked from the field. Then the hogs are turned in to clean up the waste corn in the field. Last summer cowpeas were drilled in the corn when plowing the last time. These furnished much valuable feed in addition to the corn.

In April this man had 20 head of fall pigs averaging about 125 pounds. These shoats had had no feed except wheat and alfalfa pasture and the waste grain they gathered from the field except a little corn that was thrown to them each day in the late winter and early spring. In April they were put on ground corn for thirty days. During this time each ate an average of one-fourth bushel daily. At the end of thirty days they averaged 225 pounds. This makes an average gain of 3⅓ pounds per day, or a little more than 13 pounds of gain for each bushel of corn fed. The market price of corn was 50 cents a bushel. The hogs sold at $5.50 per hundred, thus bringing 73⅓ cents a bushel for the corn fed.

This farmer raises two litters of pigs a year, farrowed in March and September, turning off fall pigs in the spring and spring pigs in the fall, selling at 6 to 8 months old. From March 15 to November 1, 1906, he turned off $720.50 worth of hogs and had 22 head in the fattening pens, all of his own raising and all grown and fattened on the products of his own farm.

Another farm in the same locality will serve as an illustration of what may be done with fall pigs in this section. Eighty head ran on the alfalfa and wheat fields of the farm during fall and winter. They gathered roughage and waste grain in the fields and were fed no grain until 6 months old. At this age they averaged 135 pounds. They were then fed some corn on alfalfa pasture, the amount gradually increasing till the pigs were on full feed. Corn was fed for two months, during which time the pigs made an average gain of 14 pounds for every bushel of corn fed. They were sold at 8 months old, weighing 235 pounds each. The price of the corn was 45 cents a bushel. This makes the cost of the corn fed $257.14, or $3.21 for each hog. At the average price of hogs in this locality, 5½ cents, the herd averaged $12.92½ per head. Deducting the price of corn fed leaves, as the value of the fall and winter pasture for each hog, $9.71.

Another farmer ran a bunch of September pigs on alfalfa and wheat pastures until the following May, when they weighed 125 pounds. They received in addition one ear of corn each twice a day. At this time the corn was increased gradually until each hog was getting 10 ears twice a day, which this farmer claims is the maximum feed for young hogs. They were fed thus for six weeks, making in this time a gain of about 100 pounds a head and consuming 10 bushels of corn each at a cost of $3.50 a head, or 3½ cents a pound for each pound of gain on corn. Allowing 4 bushels more as the quantity probably fed up to the fattening period at two ears a day, makes the cost for corn for each hog $4.90. To this adding $1.10 a head for pasture and slop (the cost of the slop fed is not known) brings the cost of each hog to $6.50 a head, or 2⅝ cents a pound. This allowed a good margin of profit at the ruling price of pork.

To show the importance of alfalfa hay in a system of feeding, the practice of the farmers around North Platte, Nebr., and elsewhere may be mentioned. The alfalfa hay is ground up fine or else fed whole with corn in the proportion of about 5 pounds of alfalfa to 1 pound of corn. This is fed to the brood sows during the winter, and they come through in excellent condition on very cheap feed. In many sections alfalfa hay is worth about $5 a ton on the farm. One ton of alfalfa and about 8 bushels of corn will keep three brood sows one hundred and thirty days, or nearly the whole winter. The hogs so kept farrow pigs that are remarkable for their vigor and size.

In these times of scarcity of labor and its high price many farmers are trying to reduce the labor on the farm. Some of the hog raisers have adopted the plan of harvesting the corn crop by turning the hogs into the cornfield and letting them gather it, or "hogging it down," as it is called.

One man in Ohio turned 122 spring pigs and older hogs into a 10-acre cornfield in September. The total weight of the hogs was 15,693 pounds. The spring pigs averaged 82 pounds and the older hogs 156 pounds. There was about the same number of each kind. The corn would yield about 60 bushels an acre, and in it there were a good many pumpkins. The hogs had access also to a 5-acre clover field from which the seed had been removed. Water was hauled to them and they had the shade of the woods near by. In twenty-eight days the hogs had gained 6,522 pounds. At this time 57 head were sold, averaging 245 pounds, bringing $5.15 per hundred. The remainder were not sold, but the farmer was offered $5 per hundred for them. Counting the entire gain of 6,522 pounds at $5 would make $327.60, or $31.20 per acre for the field. This paid 52 cents a bushel for the corn which on the market was worth 40 cents. The whole herd of hogs made an average daily gain of 1.92 pounds.

Another man in southern Kansas makes a practice of "hogging down" corn. He uses a portable fence and fences off 5 to 10 acres at a time, taking in more as needed. He turns the hogs in the corn in August. On 12 acres of corn one year he fattened 50 head of hogs, using about 600 bushels of corn. Of the bunch 42 head were sold, averaging 240 pounds, netting $600. Allowing 100 pounds gain for each hog on the corn thus fed, the corn brought 41½ cents a bushel, without the expense of gathering.

Another man in Oklahoma has been "hogging down" corn for a number of years. About 500 head of hogs are turned off this farm every year. By gathering and weighing corn beside that which was gathered by hogs, it was found that a bushel of corn "hogged down" will make as much pork as the same quantity husked and fed, while the expense of harvesting is saved; besides saving the labor of feeding the corn to the hogs the field is also cleaned up better than a husked field.

An Iowa farmer began hogging down corn several years ago, using 20 acres the first year. He watched carefully the feeding of the hogs on this field and concluded that no more corn was wasted than would have been left in the field by the average husker. Since that time he has hogged down all his corn, thus saving the expense of husking. This man says the cost of husking for one year will fence the field hog-tight if there is already a wire fence for cattle. Husking 40 acres of corn yielding 40 bushels per acre, at 4 cents per bushel—it has cost nearer 5 cents the last season (1907), figuring board, etc.—amounts to $64. If the 40 acres are a square field this allows 20 cents a rod for the fence the first year. With a cattle fence already provided this will buy the wire to make it a good hog-tight fence. Besides this there are two other great objects to

be attained by this method of harvesting corn: (1) The improvement of the land and (2) the health of the hogs. The farmer referred to says that in his first year's experience he snapped 20 acres of corn beside the field hogged down. The next spring both were sown to small grain under the same conditions and with the same preparation. The wheat on the land where corn was hogged down made 5 and the oats 7 bushels more to the acre than did the other. The difference is just as noticeable in a succeeding corn crop. The husks, cobs, stalks, and leaves all remain on the land, and these, with the manure from the hogs, enrich the soil and add organic matter to it.

The health of the hog is another important item. Hogs that have plenty of range and exercise are not nearly as susceptible to disease as those confined in a small pen. A hog that goes out after his feed will be well grown and thrifty, accustomed to the elements and not liable to be injured by a sudden change of weather. It is difficult to put a good finish on hogs while running in a large pasture. If they are allowed to run on good pasture until three weeks or a month before sending to market, and are then shut up and given all the corn they want, with plenty of pure water, they will make very rapid gains.

This man allows his pigs to run in the corn as soon as the land is plowed the last time, but does not let the older hogs into the field until the corn is in good condition to feed in the fall. He says he has also had good results from letting cattle into the corn first and following these with hogs. He thinks this is the most practical solution of the labor problem when help is so high-priced and scarce.

As stated in the beginning, it is the aim in this bulletin to deal with some of the practical problems that are confronting the farmers of this country. Facts that have come under the writer's observation in the past year (1907) have been stated as concisely as possible and applied to the territory visited and to similar latitudes. It is impossible, as already stated, to prescribe for the wants of each individual farmer in the limits of a bulletin such as this. The facts are given in a general way, and it remains for each hog raiser to pick and choose for himself as his judgment dictates.

B. P. I.—322.

THE CULTURE AND USES OF BROME-GRASS.

By R. A. Oakley, *Assistant Agrostologist, Forage Crop Investigations.*

INTRODUCTION.

It is the purpose of this bulletin to describe some of the more general methods used in the growing and utilization of brome-grass in the sections where it is now of most importance, and not to discuss in complete detail its culture throughout the entire United States. While the methods described are those employed in North Dakota, South Dakota, and the Canadian Northwest, they are also applicable in general to all other sections where this grass can be grown. The treatment given the subject is slightly inconsistent, since the methods actually practiced by the farmers and the suggestions and conclusions drawn by the writer from his investigations are combined in such a way as not to make them entirely distinct. It is hoped, however, that the matter will in this form be of more assistance to those contemplating the growing of the grass than were another plan of arrangement followed.

Brome-grass (*Bromus inermis* Leyss.), sometimes called smooth brome or Hungarian brome, is a vigorous perennial grass, possessing aggressive underground rootstocks by which it propagates readily. In general, it grows from 15 to 30 inches high, but under exceptionally favorably conditions it attains a height of 4 feet or more. The seed is borne in an open panicle closely resembling that of the well-known chess, or cheat, and is produced abundantly. (See Pl. V, fig. 1.) Although the grass is inclined to mat at the base, the entire stem is also quite leafy. (See Pl. V, fig. 2.)

Brome-grass was introduced from Europe about 1880 and has attained considerable importance in North Dakota, South Dakota, and the Pacific Northwest. It is grown in this country to some extent throughout the general region from Kansas north to the Canadian boundary and west to the Pacific coast, but its importance in the timothy and clover region is at present very limited. The grass is capable of withstanding severe cold and extended periods of drought, but it is seriously affected by heat, and consequently can not be grown successfully south of the southern boundary of Kansas except at high altitudes or under otherwise favorable conditions. It does well on

a variety of soils, but gives best results on soil that is well supplied with humus. It can, however, be grown very successfully on sandy or gravelly land.

In the Dakotas and the closely adjacent sections brome-grass is of more importance than in any other portion of this country. It has been grown in this region for twelve or fifteen years, but is as yet not so widely distributed as would be expected. Improved methods of growing alfalfa, making that crop more certain, are in a measure responsible for the comparatively limited use of brome-grass. This is true more especially in South Dakota than in North Dakota. In sections where alfalfa can be grown brome-grass can not compete with it as a hay crop. In the more humid portion of the above-named States and on the better classes of soil it has the reputation of being difficult to eradicate, and, whether this is warranted or not, this belief has a decided tendency to make the grass unpopular in such sections. For the above reasons and because there is still a considerable quantity of native hay produced, and consequently not such a pressing demand for cultivated grasses, brome-grass has not attained more importance than is the case at present.

METHODS OF CULTURE.

PREPARATION OF THE SEED BED.

For the preparation of the seed bed it is the common practice to plow the ground as early as possible in the spring, which in most sections is in March or very early in April. It is then put into condition for seeding by a thorough harrowing, or by disking, harrowing, and rolling. A careful preparatory treatment is considered essential in the securing of a good stand of grass. Some successful growers favor fall plowing, since this puts the land in better condition for seeding in the spring. Brome-grass follows all crops with practically the same results. It does well after corn, as well-cultivated corn ground is usually quite free from weeds. Wheat and oats, however, are most commonly the preceding crops.

SEEDING.

The seed is usually sown during the first part of April or as soon as the weather is favorable, which may be even as early as the latter part of March. One bushel (14 pounds) to the acre is considered by most growers to be a sufficient quantity of seed to produce a satisfactory stand, and good results are often obtained with 10 to 12 pounds. At the Manitoba experimental farm 10 pounds of good seed is recommended, and 10 to 12 pounds at the Saskatchewan experimental farm.

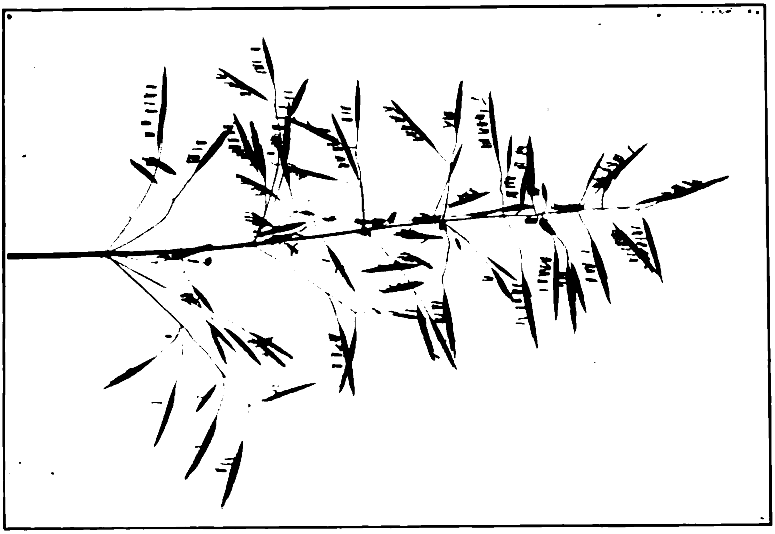


FIG. 1.—A PANICLE OF BROME-GRASS (BROMUS INERMIS) IN FULL BLOOM.

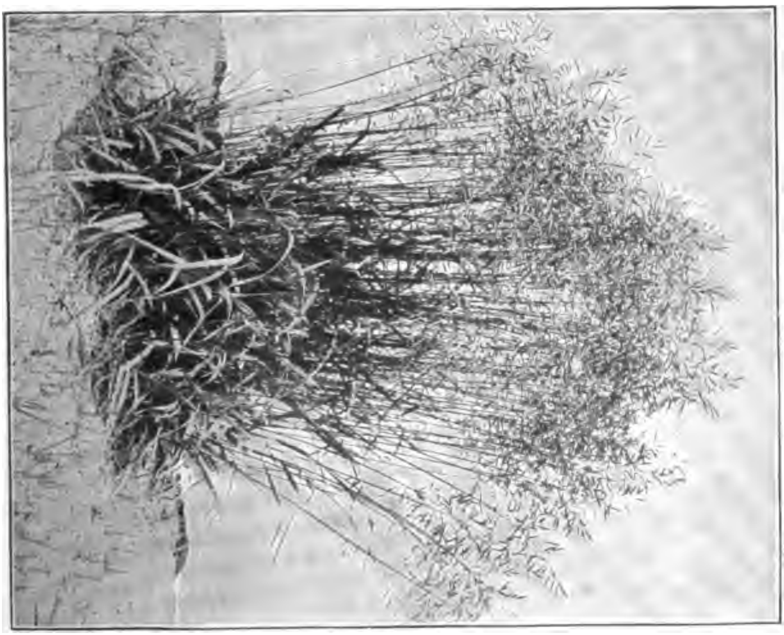


FIG. 2.—A SINGLE PLANT OF BROME-GRASS (BROMUS INERMIS).

If desired for pasture alone, it is considered well to sow as much as 20 to 25 pounds to the acre, since this quantity gives a stand that will make good grazing sooner after sowing than a light seeding. Heavy seeding is advised for sections where the grass is being introduced or is not commonly grown. The decrease in recent years in the quantity of seed sown to the acre is due to the fact that home-grown seed is used and better methods are employed in cleaning and sowing it.

The amount of rainfall in any section usually determines whether the seed is sown with or without a nurse crop. In general, in the eastern half of the Dakotas a nurse crop is used, while in the western part, where the rainfall is less, the grass is sown alone. Wheat, oats, barley, and spelt are used as nurse crops and are usually sown at the same rate as when sown alone. The grass seed is sometimes mixed with the grain, but it is a more common practice to drill in the grain, sow the grass broadcast afterwards, and cover by harrowing across the drills. In sowing brome-grass seed with grain it is often difficult to prevent it from being covered too deeply, which usually results in an uneven stand. Difficulty is also often experienced in getting a mixture of grain and grass seed to feed evenly through the drill.

Even in the more humid sections of the Dakotas there is some difference of opinion as to the advisability of using a nurse crop. The best argument in favor of this practice is that returns are obtained from land which otherwise would be practically idle for one year, as the grass yields nothing the first season, even though sown alone. Seeding alone, however, usually gives a better stand, except, perhaps, on weedy land, in which case a nurse crop is quite effective in keeping down the weeds.

In the less humid sections, where brome-grass is most commonly sown alone, the preparation of the seed bed is essentially the same as in cases where a nurse crop is used. When the seed is sown with a drill, it is a good practice to harrow afterwards, as this treatment leaves the ground in a better condition to conserve moisture. The only objection to this method is that it is likely to cover the seed too deeply.

Where fall wheat is grown, brome-grass is sometimes sown with it. By the time the wheat is cut the next summer the grass has made a good growth, and a heavy crop of hay is secured the year following this. Throughout the entire brome-grass region there is some fall seeding done, the time of seeding varying from July to October.

Whether sown in the spring or fall, with or without a nurse crop, brome-grass generally does not make a very vigorous growth and yields practically no forage or seed the first season. When sown alone it is found necessary to mow the grass once during the summer to keep down the weeds. In this case the cutting should be allowed

to remain on the ground. Aside from this, the field receives no attention and in most cases it is not pastured in the fall. When grazed during the autumn of the first year care should be taken to avoid overpasturing.

RENEWAL OF MEADOWS.

Under ordinary conditions a meadow of brome-grass will remain productive for three or four years, depending largely on the kind of soil and the nature of the treatment which it receives. Although it has been grown for a number of years in this country, there has been very little done in an experimental way by farmers to determine the best methods of renewing old meadows. In the Canadian Northwest more attention has been given to this subject, and farmers there have obtained very good results by their methods.

The history of a field of brome-grass is in general as follows: During the season in which it is seeded very little is obtained from it, except, perhaps, a small amount of pasturage; the next year a very fair crop of hay is secured; the third year, a maximum crop; the fourth year the yield is considerably reduced; and following this it decreases rapidly, owing to the meadow becoming what is commonly called "sod-bound." As before stated, the decrease in yield after the third year depends to a large extent on the kind of soil, since on heavy, rich soils the grass usually remains productive for a longer period. The character of the season also is thought to have an effect on the life of the meadow, and some farmers are of the opinion that if conditions are exceptionally favorable for a large crop the second year the grass has a tendency to diminish in yield earlier than if an ordinary crop was produced at that time.

The method of renewal giving best results in the Canadian Northwest and also practiced to some extent in the Dakotas is that of shallow breaking, the time of year depending largely on the amount of rainfall. The experimental farm at Brandon, Manitoba, recommends that the meadow be plowed about 2 inches deep in June or early July, after a crop of hay has been removed, the sod being then rolled and worked down thoroughly. As a result of this treatment a good crop of hay is secured the following season. Farther west, in Saskatchewan and in the drier portions of the Dakotas, breaking the meadow in the spring, about May, gives best results. This method is recommended by the experimental farm at Indian Head, Saskatchewan. Satisfactory results have been obtained in the more humid sections from shallow-breaking the sod in the spring and putting it in condition for a light seeding of grain, oats being frequently used. If thought necessary, 6 to 8 pounds of brome-grass seed is added. In this way a crop of grain is secured the same year, and a good crop of grass the next, so that the ground is not

allowed to lie idle. Returns are of course obtained from the land if the breaking is done in June or July after cutting a crop of hay. In the drier portions spring plowing is necessary, but since grain can not be sown on the sod no returns are obtained until the following year. Good results are sometimes secured from breaking the sod in the fall and sowing oats or some other small grain in the spring. When this is done the grass comes on for a full crop the next year. This method, however, is not commonly practiced.

Disking appears to give better results in the humid than in the drier sections, but in general it can hardly be said to give entire satisfaction. Better results are obtained on sandy or loose soil than on a heavy soil where a tough sod is formed. Farmers who have done very little toward improving their meadows are commonly of the opinion that disking is an effective means of renewing them, but actual experiments indicate that the value of this treatment is considerably overrated. Harrowing with a drag harrow in July after the hay is cut has proved beneficial in some instances.

The practice of applying barnyard manure to unproductive meadows has not been followed to any great extent, and under present conditions it is hardly practicable. The results obtained from such treatment have not been very definite, and in some cases they have been quite contradictory. That a liberal application of barnyard manure, even when no other treatment is given, will materially increase the yield of hay from a so-called "sod-bound" meadow has been proved by reliable and successful farmers. Best results have been obtained by applying an even top-dressing early in the spring before the grass begins to grow. Sheep manure has been found to be very beneficial.

Hardly sufficient evidence has been obtained to warrant definite statements regarding the value of various fertilizers. Prof. J. H. Shepperd, of the South Dakota Agricultural Experiment Station, in the season of 1905 obtained some results that were very favorable to the use of nitrate of soda. At the Highmore station, South Dakota, experiments conducted with the same fertilizers in 1906 gave rather indifferent results. The data available on the subject of renewing meadows by either barnyard manure or commercial fertilizers are so incomplete and the practice of renewal in this way is so unusual that it is not considered advisable to discuss the subject further at this time.

MIXTURES OF BROME-GRASS WITH OTHER GRASSES.

Some attention is being given to mixtures of brome-grass with other grasses, and very good results are being obtained. The practice

so far is very limited, and the proportions of the different grasses to use and the methods of handling have not been well worked out.

At present timothy seems to be the most common grass used in mixtures; alfalfa, red clover, slender wheat-grass, meadow fescue, and orchard grass are also used. Grasses and clovers are mixed with *Bromus inermis* to improve the quality and yield of forage and, for what is probably of more importance, to prolong the period of productiveness by keeping the brome-grass from becoming sod-bound. Results of experiments to determine this period have so far been rather indefinite. It is probable that the sod-bound condition can be delayed for a short while, but not for any great length of time. Alfalfa and clover are of value also, since they tend to maintain the productivity of the soil, and where these plants are mixed with brome-grass they can be pastured with little danger to stock from bloating.

Timothy has been grown with brome-grass at the Manitoba experiment farm with very good results, but it is the opinion there that it does not materially increase the life of a meadow and that the brome-grass eventually crowds it out. This mixture is quite commonly grown throughout Manitoba. Mixtures have been tried on the experiment farm at Indian Head, Saskatchewan, and one composed of 7 pounds of *Bromus inermis* and 7 pounds of slender wheat-grass (*Agropyron tenerum*) has given good results. A meadow of this mixture after having been down for six years without renewing still remained productive, yielding two tons of hay to the acre. In the Dakotas experiments are being conducted with alfalfa and brome-grass, and there is a probability of the combination coming into general use where alfalfa can be successfully grown. Mixtures with orchard grass and meadow fescue have given indications of being worthy of attention. In all permanent mixtures the quantity of brome-grass seed used should be smaller than the sum of the other constituents, as brome-grass has a tendency to crowd out the other grasses.

USES AND VALUE.

PASTURE.

Although grown as a general-purpose grass, *Bromus inermis* is much better adapted for use as pasture than for hay, on account of its tendency to form a turf. It furnishes a large quantity of palatable pasturage, and is especially valuable because it can be grazed early in the spring and late in the fall, and unless the season is unfavorable it furnishes a considerable amount of feed during the summer. Where it is now being grown there are no grasses that can equal it for pasture on sandy land, as it not only produces well on such soil, but forms a sod that withstands trampling and is not easily pulled up

by stock. This is an important feature, especially where sheep are grazed. Even after the grass has become sod-bound and produces only light yields of hay it can still be pastured profitably for two or three years. While it is impossible at the present time to secure definite data in regard to the carrying capacity of *Bromus inermis* pastures, it can be conservatively stated that both in favorable and unfavorable seasons they furnish more grazing in the western part of the Dakotas than the native grasses and more in the eastern part than Kentucky bluegrass.

HAY.

Brome-grass is not an ideal hay grass, although for two or three years after sowing it gives a satisfactory yield of a very good quality of hay. On rich land the yield is better than the average for standard grasses, and the quality is good. (See Pl. VI, fig. 1.) It is generally agreed that the best stage at which to cut brome-grass for hay is just after it has passed full bloom and is in the condition known as the "purple." The practice is, however, quite elastic in this respect, as the grass makes hay of good quality when cut either before or after this stage. No definite feeding experiments have as yet been conducted to determine the value of brome-grass hay in comparison with other standard hays or fodder, but general experience indicates that it is almost, if not quite, equal to timothy for cattle (especially dairy cows), for horses not at work, and for sheep. When properly cured it is very palatable and is relished by all classes of stock, but on account of its laxative properties it can not be recommended as a feed for livery horses or horses at hard work.

Different writers in discussing brome-grass disagree in regard to its nutritive value as compared with a standard grass such as timothy. Chemical analyses disagree also, and it is difficult to compare these grasses, since the samples have been taken at different stages of maturity and also under otherwise different conditions. The average of analyses given in Bulletin 56 of the Iowa Agricultural Experiment Station shows water-free samples of *Bromus inermis* to contain 3.48 per cent of fat and 14.14 per cent of protein, and samples of timothy under the same conditions to contain 4.83 per cent of fat and 12.27 per cent of protein. These analyses indicate that the grasses are near enough alike to be of equal feeding value. The verdict of the feeder, however, is in most cases to be taken in preference to that of the chemist, and it is doubtful whether brome-grass will ever be considered quite equal to timothy as feed for stock.

Brome-grass is usually ready to cut for hay from the last of June until the 20th of July, depending on the locality. When conditions are favorable, it is possible to secure two cuttings, the first about

the last of June or early in July, and the second in September. The securing of two crops depends almost entirely on the amount of moisture and very little on the latitude, since in eastern Manitoba two are frequently obtained. Except under irrigation, only one cutting can usually be secured in the western part of the Dakotas or at the same longitude in Canada. The first cutting yields more and is of much the better quality. The second cutting, although nearly as tall as the first when cut, consists mostly of leaves and makes very light hay.

The hay does not cure as easily as timothy and darkens rapidly if allowed to get wet. Although this makes it unsalable, its feeding value is not seriously impaired. Even when properly cured, however, the hay is of darker color than timothy.

Stacking is done with the ordinary hay-making machinery, and when put up with reasonable care the stacks shed water well and will keep for two years in excellent condition, with but a small quantity of damaged hay on the outside. (See Pl. VI, fig. 2.)

As previously stated, in the third season of growth the maximum yield is usually secured. After two crops are obtained the yield rapidly diminishes. The average yield for the time the meadow is profitable, which is three or four years, may be conservatively estimated at 1½ tons per acre. This is the estimated average yield for the entire region. On good soil and under favorable conditions yields as high as 3 to 4 tons are not uncommon, especially when two cuttings a year can be secured.

Brome-grass hay is very little known on the city market and the demand for it is entirely local. It commands a good price in sections where it is grown, and ordinarily sells for $2 to $3 a ton more than native wild hay and for about the same price as timothy.

SEED.

There is a considerable quantity of brome-grass seed produced throughout the entire region under discussion, although it is grown to the largest extent in the eastern part of the Dakotas, in Manitoba, and in eastern Saskatchewan. The growing of seed in large quantities seems to have been more of an industry a few years ago than it is at the present time. It should not be inferred from this that the total quantity produced is not as great as heretofore, but that farmers are growing it less for wholesale market and more for local use, making its production more generally distributed. Whether there is actually less produced it is difficult to state; there is certainly less imported than formerly. There are many farmers who have in the past grown 100 acres, and even much more, for seed who at the present time are raising little more than enough for their own use.

FIG. 1.—A FIELD OF BROME-GRASS IN NORTH DAKOTA.

FIG. 2.—STACKING BROME-GRASS IN NORTH DAKOTA.

HARVESTING THE SEED.

The seed is mature and ready to cut from July 10 to August 1, and the stage of maturity is commonly termed the "brown" to distinguish it from the "purple," or the stage when the grass is cut for hay. Harvesting the seed is a comparatively easy matter and differs very little from the harvesting of ordinary cereals. The binder and the header are both used, but the former is the most generally employed. When the binder is used the grass is usually cut as high as possible and the bundles put in long shocks to facilitate curing. They are allowed to remain in shocks until thrashed. When the grass can be cut sufficiently high a crop of hay is obtained from the stubble as soon as possible after the seed is removed. This hay is of very fair quality, as it contains a large quantity of green leaves.

While the binder is most commonly used in harvesting, heading appears to be the best method. When it is used, almost all of the grass is left for hay, which makes quite an additional yield from the meadow. After heading, the seed is put up in well-built shocks for curing, and is usually left there from ten days to two weeks or even longer. If conditions are exceptionally favorable, it is possible to thrash directly from the header box. This is not frequently done, since the thrashing machines are not usually ready at that time of the year. The stubble is cut for hay as soon as possible after heading, and yields on an average about a ton to the acre.

Occasionally the grass is cut with a mowing machine and put in ordinary stacks for thrashing. This method is not considered desirable on account of the waste and difficulty in handling.

THRASHING.

Brome-grass is thrashed with the ordinary machine having special riddles and with the wind shut off from the fan to prevent the seed from blowing over. Difficulty is often met with in getting the cleaned seed to elevate properly in the machine, and in many cases the elevator is removed and the seed delivered from the spout at the bottom of the separator. The seed is likely to contain a great amount of chaff and broken pieces of straw after thrashing. This trash is sometimes quite difficult to separate from the seed, and it is necessary to run it through a fanning mill. By withdrawing the bundles from the cylinder after the heads have been thrashed, the seed is kept comparatively free from straw and chaff. This method involves much work and is hardly practicable where a large quantity is to be thrashed.

YIELD OF SEED.

The yield of seed is so variable, depending on the climate, soil, lay of the meadow, and other factors, that it is difficult to estimate the average quantity produced to the acre. From 250 to 350 pounds is, however, a conservative estimate. Records of the Saskatchewan experimental farm show the yield of brome-grass seed there to range from 250 to 600 pounds. Experiments conducted at the Manitoba experimental farm indicate that the harvesting of a mature crop of seed materially lessens the yield of either hay or seed the following year.

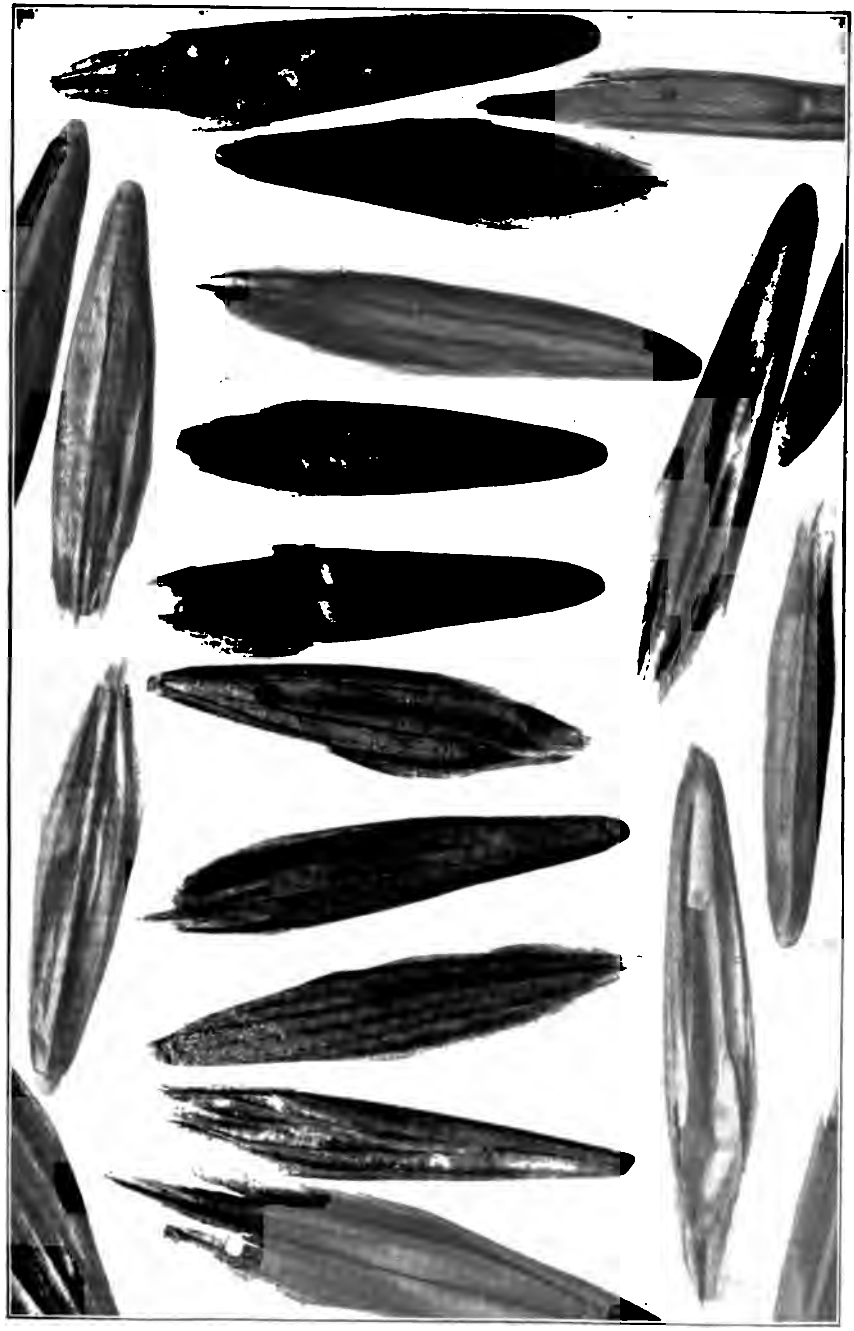
On account of the close sod formed by the grass after the first year there are very few weeds present in the fields, and consequently the seed when harvested is practically free from impurities and in very few cases are there seeds of any other grasses in it. There is occasionally a very small amount of seed of the grain used as a nurse crop and a trace of cheat (*Bromus secalinus*) and slender wheat-grass (*Agropyron tenerum*). The seeds of *Bromus inermis* are very similar to those of the above species, the seeds of chess, especially, often being mistaken for brome-grass seeds. (See Pl. VII.)

STRAW.

When cut with a binder, the straw after thrashing is generally stacked and used for feed. The quality varies largely with the height at which the grass is cut, the length of time it stands in the shock, and the care with which it is stacked after thrashing. If all these conditions are favorable, brome-grass straw is about equal to oat straw. At any rate, it makes very fair feed for wintering cattle, horses, and sheep.

USE IN ROTATION.

One of the objections which farmers have to brome-grass is that it is comparatively short lived and will not remain productive for hay in a meadow more than three or four years. This objection is not serious from the standpoint of crop rotation, but, on the other hand, is slightly advantageous, since there is a general tendency to grow one crop on a field for too long a period. *Bromus inermis*, however, is not looked upon by farmers as a valuable constituent in a crop rotation. This is due to the fact that it is considered difficult to eradicate, and when ordinary methods are employed it takes about two years to get it out of the field. Farmers desire something that can be disposed of easily in one year or with one plowing, and consequently are favoring slender wheat-grass (*Agropyron tenerum*), which is now coming into popularity on this account.



SEEDS OF BROME-GRASS (BROMUS INERMIS).

(Magnified six diameters.)

PREPARATION OF BROME-GRASS MEADOWS FOR OTHER CROPS.

The breaking up of a brome-grass meadow and the preparation for other crops is a very important matter. It has been found at the Manitoba experimental farm that plowing the sod after a crop of hay has been cut and the aftermath has made a growth of 3 or 4 inches gives very satisfactory results. The plowing may be done the latter part of June or the first of July and the sod back-set either in the fall or early in the spring and put in condition for wheat or other grains by disking and harrowing. If the aftermath is allowed to grow to the extent above indicated, it assists very materially in rotting the sod and also supplies additional humus. When the breaking is done immediately after a crop of hay or seed is harvested, the sod does not rot well, especially if the season is dry, and consequently the ground is in poor condition for a crop the following spring.

A method which has been found to be practicable, at least in the eastern portion of the Dakotas, is to break early in the spring after the grass gets a good start, then disk and roll thoroughly, and in June sow to flax at the rate of about half a bushel to the acre. In this case, unless the flax makes a good stand there will be some danger of the brome-grass making a sufficient growth to become troublesome. Where flax is a successful crop, it can follow brome-grass to good advantage. No matter what method is practiced, the grass is likely to give trouble the first season on account of its persistence, but if properly handled will not be a serious menace. It is necessary in the drier sections to break the sod when the moisture conditions are favorable, whether in fall or spring, as it is very difficult to break and does not rot readily. On account of the latter fact the sod requires considerable working in the sections of low rainfall.

MISCELLANEOUS USES.

The aggressive nature of brome-grass fits it for certain uses and situations for which the common standard grasses are not adapted. It is very valuable for putting heavy new land in condition for other crops. The rich heavy soil of river bottoms, which are frequently covered with a dense growth of weeds and brush, may be put in good condition by seeding heavily after clearing and plowing. At the end of two years the grass comes on to the exclusion of the weeds and makes an excellent hay meadow.

There are certain classes of soil that after having been plowed for five or six years become very loose and blow badly and are in poor mechanical condition for ordinary crops. When *Bromus inermis* is grown on such land for a few years it adds a sufficient amount of

humus to the soil to return it to good condition. The grass is also very valuable for preventing sandy land from blowing.

Brome-grass is an excellent crop for combating such weeds as foxtail, or squirrel-tail (*Hordeum jubatum*), and on moist land, where the latter flourishes, the former excludes it very effectually.

THE AGRICULTURAL EXTENSION OF BROME-GRASS.

Little has been done in the matter of extending the growing of *Bromus inermis* farther east at the same latitude as its present region. Experiments that have been conducted with it in various sections east of Minnesota and north of Kansas indicate that it is worthy of extension. It will doubtless prove valuable on sandy soil in Wisconsin, New York, and New England, but will probably be of use mostly as a pasture grass and in mixtures with other grasses. In parts of Ohio, West Virginia, Pennsylvania, Maryland, and Virginia where tested it has shown considerable promise. South of these States it is of questionable value.

Brome-grass should be given a thorough test as a sand-binding grass along the Lakes and near the seacoast, as its extensive root system and its ability to thrive on sandy land make it well adapted to such situations. Some very striking results have been obtained with it on sandy soil on the upper peninsula of Michigan. Under similar conditions in Wisconsin its value, especially as a pasture grass, has been quite thoroughly demonstrated. In these States it is said to be at least ten days earlier for pasture in the spring than the ordinary standard grasses.

While the thorough testing of brome-grass by farmers in the States mentioned is strongly urged, its use on a large scale is not considered advisable until its value as compared with the standard grasses commonly grown in these States has been more definitely demonstrated.

SUMMARY.

Brome-grass (*Bromus inermis*) is at present of most importance in the Dakotas and sections adjoining these States, but is grown to some extent throughout the general region from Kansas north to the Canadian boundary and west to the Pacific coast. Its importance in the timothy region is as yet very limited.

It is the common practice to sow the seed in the spring about the 1st of April, or as soon as the weather is favorable. One bushel of 14 pounds is considered a sufficient quantity to produce a satisfactory stand, and good results are obtained with 10 to 12 pounds. Heavier seeding is recommended in sections where the grass is being tested or where it is intended for pasture alone.

Under ordinary conditions a brome-grass meadow remains productive from three to four years, after which it becomes what is commonly called "sod-bound." The meadow can be successfully renewed by breaking the sod lightly, the time of breaking depending largely on the annual rainfall.

Mixtures of brome-grass with other grasses and clovers have proved very satisfactory as far as they have been tried. Timothy, slender wheat-grass, orchard grass, meadow fescue, alfalfa, and red clover are used in these mixtures.

Brome-grass is a valuable general-purpose grass, but is much better adapted for use as pasture than for hay, as it furnishes a large amount of grazing, especially in the spring and late in the autumn. The yield of hay which it produces is good and the quality very satisfactory.

The seed habit of brome-grass is good, which makes it comparatively easy to harvest and thrash. Average yields of about 300 pounds to the acre are obtained.

In crop rotation brome-grass has not as yet become well established, and by some it is looked upon rather unfavorably on account of being somewhat difficult to get out of the land. Good crops, however, are raised after it, and it adds a considerable amount of humus to the soil.

It is often difficult to prepare brome-grass sod for succeeding crops, as it does not rot readily, and for this reason it is necessary to backset after breaking. The time of breaking depends on the rainfall.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 111, PART I.

B. T. GALLOWAY, *Chief of Bureau.*

THE LARKSPURS AS POISONOUS PLANTS.

BY

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CONTENTS.

ILLUSTRATION.

THE LARKSPURS AS POISONOUS PLANTS.[a]

INTRODUCTION.

Throughout the United States many species of larkspur (Delphinium) occur. Some of these form an important feature of the western landscape;[b] others, such as *Delphinium ajacis*, on account of their beauty have been cultivated in gardens, from whence they have escaped and become a pest to the farmer.[c]

The genus Delphinium is in a very confused condition botanically and needs revision.[d] However, the botanical characteristics of the genus are clearly marked and constitute sufficient reason for considering any plant bearing them as deserving of suspicion. *Delphinium trolliifolium* Gray, represented in the accompanying illustration (Plate I), shows these characteristics. In Canada[e] and in our Western States, especially in Colorado and Montana, various species of Delphinium have been accused of stock poisoning, although feeding experiments with these plants have varied in their results, and opinion in the West has been by no means uniform as to their poisonous properties. According to Wilcox,[f] in Montana 600 sheep were poisoned by *Delphinium menziesii* on one ranch, of which 250 died. In India the

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[a] Of the many kinds of plants of the western ranges poisonous to stock, various species of larkspur are among the most destructive, especially in the mountainous regions of Colorado, Wyoming, and Montana.

About two years ago a study of the poisonous properties of one of the most common species was undertaken cooperatively by the Colorado Agricultural Experiment Station and the Office of Poisonous-Plant Investigations, the field collections and field tests being carried on by Dr. George H. Glover, veterinarian of the station, and the technical laboratory studies by Dr. A. C. Crawford, Pharmacologist of the Bureau of Plant Industry. The principal results of Doctor Crawford's work are here summarized.

It is shown that this larkspur is most virulent in its early stages and becomes much less active toward flowering time. The importance of the functions of elimination in bringing about recovery is also clearly indicated, and the significance of this fact in harmonizing the varying results of different investigations is pointed out.—Rodney H. True, *Physiologist in Charge of Poisonous-Plant Investigations.*

[b] Meehan, T. Delphinium Bicolor. Meehan's Monthly, vol. 12, p. 1. 1902.

[c] Rept. Comr. Agr. for 1865, p. 510.

[d] Huth, E. Monographie d. Gattung Delphinium. Bot. Jahrb., vol. 20, p. 322. 1895.

[e] Noxious Weeds and How to Destroy Them. Government of Northwest Territory, Dept. Agr. Bul. 2, p. 27. 1900.

[f] Chesnut, V. K. Preliminary Catalogue of Plants Poisonous to Stock. Ann. Rept. Bur. Animal Ind., 1898, p. 400.

dew from *D. brunonianum* is said to poison stock, and *D. vestitum* is claimed to be poisonous to goats.[a] Similar reports come from France.[b] Chesnut and Wilcox, in particular, have brought this subject to public attention, Wilcox's field notes and post-mortem records being especially suggestive.[c]

The main symptoms seen in the poisoning of sheep by *Delphinium menziesii* were a stiffness of the limbs, with awkward gait; associated with this were involuntary muscular twitchings and loss of muscular coordination. Convulsions with marked rapidity in the pulse rate occurred. The respiration became shallow, but finally rapid. Wilcox fed the chloroform and benzol extracts of the dried plant to sheep, causing typical symptoms. He also called attention to larkspur poisoning in cattle.[d] This work was continued by Chesnut and Wilcox.[e] They fed and injected extracts of tall larkspur (*Delphinium glaucum*) and of purple larkspur (*D. bicolor*); but although these extracts produced some symptoms in rabbits and in sheep they failed to kill.

Nelson pastured a sheep during May in an area in which *Delphinium menziesii* was growing. This sheep ate all the Delphinium she could obtain herself, and in addition was fed 1,133.92 grams more, but showed no symptoms. A second sheep was fed 1,111.3 grams of the fresh plant in five days, but showed no symptoms. During the experiment this animal was deprived of all feed save the Delphinium.[f] Irish[g] experimented by feeding the plants growing in May to steers, feeding the tops of 24 plants of *D. trolliifolium* to one and thé roots to another without results. He also fed 30 plants of white larkspur without results. He fails to state, however, how long his feeding continued. Glover's experiments[h] with rabbits were rather misleading, some dying, but most survived. Gerlach[i] fed *D. consolida* to sheep without results.

[a] Watts, G. Dictionary of Economic Products of India, vol. 3, pp. 64, 70. 1890.

[b] Delaford, P. Traitè sur la maladie de sang des bêtes à laine, Paris, 1843, p. 173.

[c] Wilcox, E. V. Larkspur Poisoning of Sheep. Montana Agr. Expt. Sta. Bul. 15. 1897.

[d] Wilcox, E. V. Poisonous Plants of Montana. Montana Agr. Expt. Sta. Bul. 22, p. 45. 1899.

[e] Chesnut, V. K., and Wilcox, E. V. Stock-Poisoning Plants of Montana. U. S. Dept. Agr., Div. Botany, Bul. 26, p. 65. 1901.

[f] Nelson, S. B. Feeding Wild Plants to Sheep. Proc. Sec. Ann. Meeting Assoc. Expt. Sta. Veterinarians. 1898. U. S. Dept. Agr., Bur. Animal Ind., Bul. 22, p. 11.

[g] Irish, P. H. Plants Poisonous to Stock. Oregon Expt. Sta. Bul. 3, p. 25. 1889.

[h] Glover, G. H. Larkspur and Other Poisonous Plants. Colorado Agr. Expt. Sta. Bul. 113, p. 17. 1906.

[i] Dammann, C. Gesundheitspflege, 1886, p. 841.

DELPHINIUM TROLLIIFOLIUM, GRAY.

LABORATORY EXPERIMENTS WITH DELPHINIUM CAMPORUM.

Specimens of *Delphinium camporum* were sent from Fort Collins, Colo., for testing in the laboratory of Poisonous-Plant Investigations. Five grams of the dried and powdered plant were accurately weighed and then extracted over night with 20 c. c. of water and 10 c. c. of 95 per cent alcohol. The alcohol was added mainly as a preservative. The following day the extraction and squeezing were continued until the fluid became colorless. The fluid was evaporated on the next day in vacuo at about 40° C., and the residue was dissolved in water and made up to 30 c. c.—perfectly arbitrary figures. Of this aqueous solution 1 c. c. injected subcutaneously into a guinea pig weighing 730 grams caused no disturbance, and 3 c. c. were also without effect, whereas 6 c. c. killed the same guinea pig in 55 minutes. A solution of 4 c. c. injected into a guinea pig weighing 352 grams caused no symptoms, while 6 c. c. injected into another guinea pig weighing 285 grams killed in 33 minutes. Later, 5 c. c. killed a guinea pig weighing 196 grams in 55 minutes, while 4 c. c. injected into a guinea pig weighing 299 grams gave no symptoms. Evidently the lethal dose of this solution lies between 4 and 5 c. c. The solution used in the above experiments was made from plants collected on April 26, 1905.

On May 16 another lot of material was collected, and a solution corresponding to 4 c. c. of the first batch was injected into a guinea pig weighing 455 grams without producing any symptoms. However, 5.3 c. c. of this solution killed a guinea pig weighing 350 grams, but a much longer period elapsed before death occurred than with the extract of the first material.

In June another lot of material was collected, and a solution of this corresponding to 4 c. c. caused no symptoms in a guinea pig weighing 376 grams; 5.3 c. c. caused no symptoms in a guinea pig weighing 500 grams, and 6.6 c. c. was inactive in a guinea pig weighing 480 grams. Of the dried material 10 grams were then extracted, and killed a guinea pig weighing 320 grams only after about 10 hours. A control amount of plain distilled water failed to kill. The lethal dose is evidently much higher than in the second stage.

There is no question as to the fact that Delphinium when injected subcutaneously will kill, and these experiments also establish the fact that the plant loses much of its toxicity as it approaches the flowering stage. It has been noted that *Delphinium consolida* is also less active when mature.[a]

Just after flowering, the purple larkspur turns yellow and ceases to

[a] Dammann, C. Gesundheitspflege, 1886, p. 1072.

be attractive, so that there is less danger of poisoning,[a] although Chesnut and Wilcox report a death in cattle from eating *Delphinium glaucum* in September.[b] The great danger early in the season seems to arise from the fact that the Delphinium appears early in the spring, and the ground may again be covered with snow, so that it is the only green plant in sight, and therefore when in an especially poisonous stage it is eaten by cattle.

A rabbit weighing 2,409.66 grams was fed January 28, 1907, with a concentrated aqueous extract corresponding to 16.66 grams of the dried plant in the second stage. No symptoms resulted. On January 30 the animal weighed 2,377.15 grams.

On January 28, 1907, a second rabbit, weighing 1,658.35 grams, was fed with a similar extract of 33.33 grams, but no symptoms resulted. Two days later the animal still weighed 1,658.35 grams.

On February 1, 1907, the first rabbit was fed an aqueous extract of 80 grams, and it died in 53 minutes with convulsions. Previous to death, paralysis of the voluntary muscles was well marked. The stomach of this animal was markedly reddened.

A rabbit weighing 1,984.41 grams on February 6, 1907, was starved 24 hours and then fed an extract of 50 grams of the same plant at 9.45 a. m. At 11.50 a. m. the animal was dull and was lying with its chin resting on the floor; at 12.25, legs paralyzed; 3.04, the animal urinated, chin still resting on the floor; 3.57, the animal could push itself around with hind legs. The following day the rabbit appeared normal. On February 11 it weighed 1,899.39 grams; February 12, 1,956.07 grams; February 13, 2,012.75 grams; March 11, 1,984.41 grams.

On February 13, 1907, a well-fed rabbit, weighing 2,097.77 grams, which had been in the laboratory for some time, was fed by stomach tube an aqueous extract of 50 grams of the same plant. This animal was observed continuously for 6 hours and appeared perhaps only slightly duller. He ate during the night, and weighed 2,119.94 grams on February 14. During the night no stools were passed. On February 16 this rabbit weighed 1,970.24 and on February 21, 2,012.75 grams.

The urine passed the first 24 hours after feeding was alkaline. Some of this was shaken with chloroform and on evaporation was taken in acid water. On evaporating off the acid, the watery solution was injected subcutaneously into a guinea pig weighing 467.76 grams, but produced no symptoms. The urine secreted in the following 24

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[a] Wilcox, E. V. Plant Poisoning of Stock in Montana. U. S. Dept. Agr., Bur. Animal Ind., 17th Ann. Rept., 1900, p. 96.

[b] Chesnut, V. K., and Wilcox, E. V. Stock-Poisoning Plants of Montana, p. 67.

hours was added to the first and the whole shaken out with benzol. This, after taking up with acid water, was injected into the same guinea pig. The animal soon became very dull, walking with waddling gait when forced to move, being evidently affected by the poison. Two days later the animal was normal. The urine of a control rabbit, similarly shaken with benzol, produced no such symptoms in this guinea pig.

On February 11, 1907, an aqueous extract of 5 grams was injected subcutaneously into a rabbit weighing 666.14 grams. An hour and three minutes later the animal was unable to stand, and soon developed convulsive movements of the limbs. This animal was expected to die at any time during the afternoon, but gradually improved and appeared slightly duller than normal the following day. On February 13 it weighed 613.61 grams; February 25, 595.29 grams; and on March 16, 552.78 grams, showing a steady diminution in weight.

An extract of 9.5 grams injected subcutaneously into a rabbit weighing 2,182.79 grams was without immediate effect.

An aqueous extract of 20 grams when injected into a rabbit weighing 481.93 grams soon caused paralysis of the limbs, and the rabbit died in 32 minutes.

On February 11, 1907, a rabbit weighing 1,417.46 grams was opened under ether, and the mouths of the ureters were tied off, together with the bladder, to prevent elimination by the urine. An aqueous solution corresponding to 34 grams of the same plant was then fed by mouth. This animal remained dull all the afternoon, and at 4.45 p. m., 4 hours and 45 minutes after the feeding, he was resting with his chin on the cage. He was found dead and stiff at 9.15 p. m., having evidently died some time previous. A post-mortem showed the ureters distended and sharply outlined.

Another rabbit weighing 1,743.37 grams was prepared in a similar manner by tying off the ureters and bladder and was fed with an extract of 50 grams. In 1 hour and 47 minutes this animal was paralyzed and unable to stand, breathing very slowly, and died 6 minutes later. The ureters were found dilated as in the previous case, and the stomach was slightly reddened.

A control for these two rabbits was prepared in a similar manner at the same time as the others. Nine hours after the operation, when the two rabbits which were fed the Delphinium were dead, this rabbit was bright and running about, but was then killed with chloroform to prevent suffering.

In these cases it is necessary to consider not only the effects of nonelimination but also the fact that the power which the liver possesses of storing up and removing injurious bodies from the circulation may

be interfered with, as Mosse[a] has proved that starved and nephrectomized rabbits show histological changes in the liver cells.

On February 20, 1907, a well-fed rabbit weighing 1,403.29 grams was etherized for 12 minutes and then fed an extract of 50 grams to see if the increased toxic action of the plant was due to any interference with the metabolism caused by the ether. On February 23 this animal showed no symptoms, weighing 1,360.78 grams, and on February 25 the weight was 1,403.29 grams. The urine collected in 60 hours was shaken with benzol, as it had previously been found that much, if not all, of the active principles of *Delphinium camporum* goes into the alkaline benzol shaking by the Dragendorff method. The residue from the benzol evaporations was then taken up with acetic acid water. On removing the acid by heat a few drops were injected into the dorsal lymph sac of a male frog (*Rana clamitans*) weighing 35 grams. This animal soon became paralyzed and was unable to move, but recovered over night. The following day a few more drops were injected with the same result, showing that some of the active principle of the Delphinium was eliminated with the urine.

From these experiments it can be seen that aqueous extracts of *Delphinium camporum* will kill rabbits on subcutaneous injection, and also by mouth if the dose is large, while much smaller doses will kill if the elimination is interfered with, as by tying off the ureters, or after starving, a condition which intensifies the action, probably by accelerating absorption. What seems to be the cause of the uncertainty in the results, especially in the lack of striking results in the feeding experiments, is that no consideration was given to the fact that the poisoning in this case may be simply the resultant of the excretion and absorption of the plant; in other words, that very little of the plant may be taken up by the gastro-intestinal tract and that this may be eliminated by the kidneys before a poisonous dose has been absorbed, so that the question of poisoning becomes one of rapidity of absorption. This is well known to be the case with curare, where the administration by mouth, except in large doses, is not likely to prove poisonous unless the elimination is interfered with as by tying the ureters.[b] Consequently the conditions most favorable for poisoning on the range would be those which aid the more thorough extraction of the poisonous principle from the plant by the gastro-intestinal tract, thus favoring absorption, and those which interfere with the elimination by the kidneys or interfere with the storing of the poison by the liver, as renal and hepatic disease or lack of salts, which normally increase diuresis.

[a] Mosse, M. Ueber Leberzellenveränderungen nephrektomierter u. hungernder Thiere. Zeits. f. Klin. Med., vol. 60, p. 373. 1906.

[b] Brunton, T. L. Text-Book of Pharmacology, 3d ed., London, 1893, p. 38.

A striking feature about these rabbits is that in some cases while the dose was not sufficient to kill immediately they gradually lost in weight, probably a direct result of the irritation of the gastro-intestinal tract. This condition may find its parallel in stock removed from a Delphinium area. Knowles[a] and Wilcox[b] have claimed that the inhalation of a few drops of ammonia and the hypodermic injection of atropin, $\frac{1}{60}$ to $\frac{1}{4}$ gram (1 mg. to 15 mg.) for sheep, or 1 gram (60 mg.) for cattle, is the most effective medicinal treatment. Elimination by purgatives and diuretics may aid. If possible, absorption from the gastro-intestinal tract should be hindered, perhaps by lard, but the real treatment is preventive.

One member of the genus Delphinium, *D. staphisagria*, has been studied carefully, and a number of bases (delphinin, delphinoidin, staphisagrin) isolated, but much is still to be desired in the way of exact knowledge concerning these bodies.[c] Delphinin has a local irritative action. Its systemic action is mainly paralytic on the heart and respiration, and resembles that of aconitin in many respects.[d] Post-mortem examinations in poisoning by mouth with this body showed marked reddening of the stomach. In a number of Van Praag's experiments with feeding solutions of Delphinium a marked increase in urinary secretion was noted.[e] *Delphinium consolida* has also received some attention chemically,[f] while *D. leroyi*, *D. peregrinum*, and *D. mauritanicum* have been shown to produce poisoning experimentally.[g]

Recently *Delphinium bicolor*, *D. menziesii*, *D. nelsonii*, and *D. scopulorum stachydeum* have been found to yield an alkaloid, delphocurarin,[h] which has been introduced as a substitute for curare in

[a] Knowles, M. E. Larkspur Poisoning in Sheep and Cattle. New York Med. Jour., vol. 66, p. 271. 1897.

[b] Wilcox, E. V. Larkspur Poisoning of Sheep, p. 45.

[c] Dragendorff and Marquis. Ueber d. Alkaloide des Delphiniums staphisagria. Arch. f. Exp. Path. u. Pharmakol., vol. 7, p. 55. 1877.

Kara-Stojaiow, C. Ueber d. Alkaloide d. Delphinium staphisagria. Pharm. Zeits. f. Russland, 1890, vol. 29, pp. 628, 641, 657, 673, 689, 705, 721.

[d] Tamburini, N., and Leone, A. Azoine fisiol. della Delfinina. Gior. Internaz. d. Sci. Med., n. s., vol. 3, p. 985. 1881.

Orfila, M. Traité de toxicologie, 5 ed., vol. 2, p. 138. 1852.

[e] Van Praag, J. L. Delphinin. Arch. f. Path. Anat., vol. 6, p. 439. 1854.

Sereck. J. Beitr. z. Kennt. d. Delphinins. Dorpat Diss. 1874.

Darbel, A. Recherch. Chim. et physiol. sur les alcaloides du Delphinium staphisagria. Montpellier. Thèse. 1864.

[f] Masing, E. Ueber d. Alkaloid d. Feldrittersporns. D. consolida. Pharm. Zeits. f. Russland, vol. 22, p. 33. 1883.

[g] Rochebrune, A. T. de. Toxicol. Africane, vol. 1, pp. 152, 161, 353. 1896.

[h] Feinde der Haustiere und ihre giftige Principen (Delphocurarin). Pharm. Centr., vol. 44, p. 913. 1903.

vivisection work, and this introduction is indorsed by Lohmann's work.[a]

Schiller[b] corroborates Lohmann's results, but claims that curare is efficient for muscle physiological work in smaller doses than is the delphinin of Heyl.

This use of Delphinium certainly offers a field which should be investigated commercially, as curare is likely to be uncertain in its action.[c] Methyl delphinin is said also to possess this curare-like action.[d]

The coloring matter of the flowers of *Delphinium zalil* has been utilized as a dye.[e] Other Delphiniums, such as *D. ajacis*, have been recommended for insecticidal uses, and especially on account of cheapness.[f]

Froggatt states that common garden larkspur will kill locusts, and advises planting them in masses around gardens and orchards to protect against the ravages of these insects.[g] The same claim is made as to its action against grasshoppers.[h]

Delphinium coeruleum has been used to kill maggots and *D. brunonianum* to destroy ticks.[i] This latter plant has been used to some extent as a substitute for musk.

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[a] Lohmann, A. Unters. über d. Verwerthb. eines Delphinin präp. an Stelle d. Curare in d. muskelphys. Technik Pflüger's Arch. f. Ges. Physiol., vol. 92, p. 473. 1902.

[b] Schiller, V. Ueber d. physiol. Wirkungen d. Delphinins (Heyl). Arch. f. Anat. u. Physiol., Physiol. Abtheil., p. 248. 1904.

[c] Merck, E. Ann. Reports, 1902, vol. 16, p. 48.

[d] Kobert, R. Lehrb. d. Intox., 2d ed., p. 1185.

[e] Aitchison, J. E. T. Some Plants of Afghanistan. Pharm. Jour. and Trans., vol. 17, p. 466. 1887.

[f] Amer. Jour. Pharm., vol. 55, p. 50. 1883.

[g] Froggatt, W. W. Plague Locusts. Agr. Gaz. New South Wales, vol. 11, p. 181. 1901.

[h] Bailey, J. F. Hemp. Queensland Agr. Jour., vol. 2, p. 200. 1898.

[i] Watts, G. Dictionary of Economic Products of India, vol. 3, pp. 64–65. 1890.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 111, PART II.

B. T. GALLOWAY, *Chief of Bureau.*

THE FIBERS OF LONG-STAPLE UPLAND COTTONS.

H. A. ALLARD,

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ISSUED SEPTEMBER 9, 1907.

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1907.

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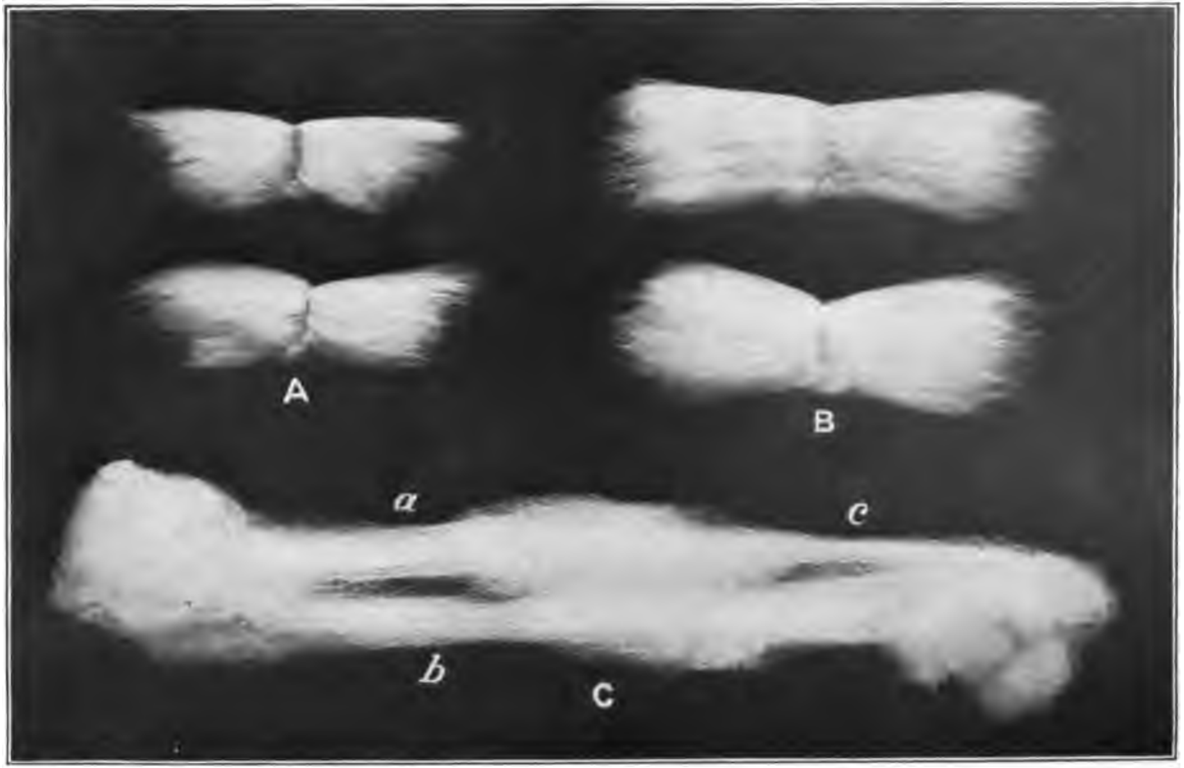
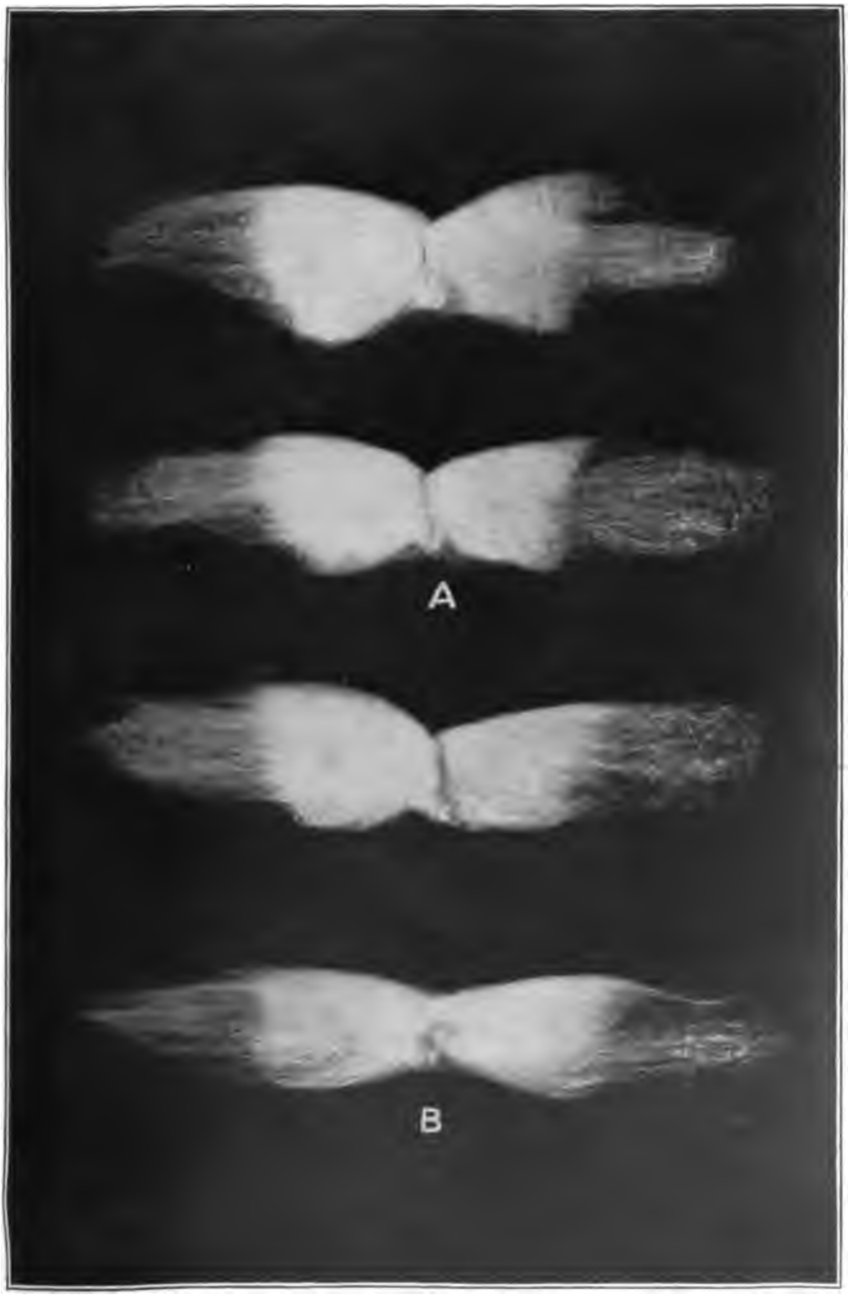


COTTON SEEDS WITH FIBERS ATTACHED.

A and *B*.—Cotton seeds with fibers combed out to show uniformity and nonuniformity in the length of the fibers. *C*.—Lock of Griffin cotton stretched so as to show points of origin of longer fibers—*a*, *b*, and *c*.



SEEDS OF COTTON COMBED OUT TO SHOW THE SO-CALLED LONGER FIBERS.

A.—Columbia variety. *B*.—Griffin variety.

B. P. I.—305.

THE FIBERS OF LONG-STAPLE UPLAND COTTONS.

UNIFORMITY OF COTTON FIBERS.

In investigations in cotton breeding where an improvement in certain lint characters is desired several factors must be carefully considered. Among these, some of the most important are fineness of lint, the relative yield of lint to the total yield of seed cotton, and the uniformity of length of all the fibers when properly combed out and examined. The last character, uniformity of length, is a most important one and has much to do with subsequent waste and the production of good yarns in the process of manufacture.

On Plate I are illustrations of cotton seeds with fibers combed out to show uniformity and nonuniformity in the length of the fibers. The seeds to the left (A) show very poor uniformity and are of the "butterfly" type, as they are commonly called. In marked contrast, the seeds to the right (B) show excellent uniformity as a result of several generations of careful selection.

APPARENT LACK OF UNIFORMITY AND ITS OCCURRENCE.

There is an apparent lack of uniformity which deserves considerable attention from the standpoint of cotton growers and breeders. Plate II illustrates this character, although it is more strikingly brought out in the operation of detaching the seed from the lock. From the illustration there would appear to be a great lack of uniformity, due to a group of fibers about twice the length of the general covering. This group arises from the center of the main body of fibers or, often, from those having a point of attachment near the larger end of the seed. This character is usually associated with the finer, more crinkly types of long-staple cottons, such as the fine, long-linted Egyptian and Sea Island varieties and the long-staple Upland varieties—Griffin, Allen, Cook, etc. It is a character which becomes more apparent as a variety is being rigidly selected generation after generation for finer, longer staple. This has been well illustrated in the improvement of the lint characters of the Russell variety and, to some extent, the Jones variety. The orginal condition

of both of these varieties is remarkably free from this so-called longer group of fibers. In the case of the greatly improved Russell strain, which has become distinctive enough in good lint characters and yield to be designated as a new variety—the so-called Columbia cotton—these longer fibers are evident to a remarkable degree.

THE TRUE NATURE OF THE LONGER FIBERS.

It has been more or less the rule with cotton breeders and cotton growers acquainted with the requisites of desirable lint characters to regard these extra-long fibers as an unfavorable feature. In this light they meant a variation toward nonuniformity. In the work of selection, to avoid as much as possible a perpetuation of this sort of variation, plants showing this character most markedly were regarded with suspicion and later even discarded, although in other respects they were among the best in the field.

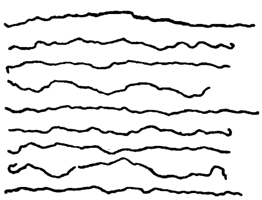


FIG. 1.—Single cotton fibers from the so-called longer group of fibers.

A careful examination leads to the conclusion that these fibers should be regarded in a wholly different light. *They are not longer fibers as they have been generally considered, but are caused by more or less curling and interweaving, which results in the pulling out of fibers from adjacent seeds.*

In the ordinary manner of stretching the locks to determine the drag, the fibers are slowly separated and drawn out, and at those points of greatest binding, as shown in Plate I, C, *a*, *b*, and *c*, the groups of longer fibers appear to rise. If, now, a single seed is selected and detached from the rest and the entire group of fibers loosened from its attachment to the seed coat in the neighborhood of the longer groups, one can with fine forceps draw these fibers out carefully and compare their length with those of the rest of the seed.

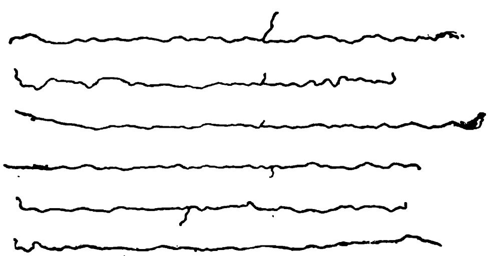


FIG. 2.—A few extra-long cotton fibers, showing two fibers united.

In many instances the single fibers now readily separate, since the tension of pulling has ceased. Several of these single fibers are shown in figure 1. In some instances fibers nearly twice the normal length are drawn out. Oftentimes with the naked eye the point of union or tying may be discerned by the tiny loose ends, as is shown in figure 2. In other cases, however, this point of union is so intimate that only a high microscopic power can make it evident. Figure 3 illustrates various

degrees of this tying or curling together, as seen when greatly magnified. In figures 1 and 2 single and united fibers, respectively, of natural length are shown, but the diameters are of necessity much greater than normal, owing to the exceeding fineness of the fibers.

The drag of cottons showing the longer fibers previously described gives a more extended, elastic tension than is manifest among the short-staple varieties. It is probable that breeders may find this character a useful one in indicating a tendency toward increased length, fineness, and crinkliness of staple in the individuals in which it occurs most noticeably—an indication of better spinning quality.

It is important that breeders and growers of long-staple cottons should know that these apparently longer fibers are no indication of true lack of uniformity. The presence of these fibers in the long-staple Upland varieties has quite universally led to the erroneous belief that such cottons are rather inferior in uniformity as regards length of fibers. The Griffin cotton, in particular, recognized in other respects as the best long-staple Upland cotton grown, has always been described as decidedly unsatisfactory so far as uniformity in length of staple is concerned, since the drawing out of fibers from adjacent seed is a marked characteristic of this variety.

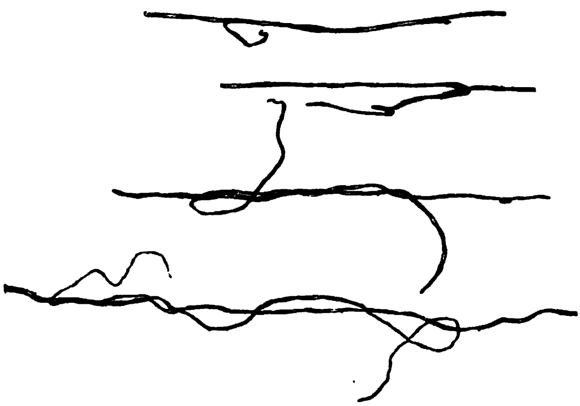


FIG. 3.—Cotton fibers tied together, very much magnified.

A knowledge of the true nature of these longer fibers will clear the reputation of some of the best long-staple Upland varieties of a serious fault hitherto wrongly attributed to them by all breeders and growers.

111-11

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 111, PART III.

B. T. GALLOWAY, *Chief of Bureau.*

IMPORTED LOW-GRADE CLOVER AND ALFALFA SEED.

BY

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AND

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IMPORTED LOW-GRADE CLOVER AND ALFALFA SEED.

INTRODUCTION.

During the calendar year 1906 the United States exported 3,615,873 pounds of clover seed, and during the latter half of the same year imported 6,306,561 pounds, the exports for the year being only a a little more than one-half the imports for six months. The same condition holds true with alfalfa seed, the imports far exceeding the exports. The relatively large importation of these seeds results from short crops in this country and a constantly increasing demand on account of the new land being brought under cultivation and the extension of diversified farming.

Illustrations of typical samples of imported red clover and alfalfa seed of good quality and that of low grade are shown in Plate I.

WHY LOW-GRADE SEED IS IMPORTED.

In Europe seed testing has been gradually growing in favor for forty years and is now recognized as an important aid to agriculture. All the European countries, with the exception of Spain and Turkey, have seed-testing stations, varying in number from one in Italy to twenty-eight in Germany. Each of them has the necessary equipment for making complete tests of seed, both for mechanical purity and for germination.

The test for mechanical purity as conducted in these stations includes not only the determination of the percentage of pure seed and of other seeds and dirt, but also the size and source of the seed. The source of the seed is determined by the characteristic weed seeds which are found. While errors are no doubt made, these determinations are of great value in showing that at least a part of the seed was raised in a certain section, and they furnish information as to the probable adaptability of the seed to local conditions. Through the work of these stations the people have come to appreciate the importance of good seed, and as the greater part of that now used in Europe is sold on the basis of accurate tests for mechanical purity and germination the sale of low-grade seed has been greatly reduced.

A similar condition exists in Canada, where there is a strict law governing the quality of seed sold. In this country, however, only

three States have any effective legislation restricting the sale of seeds within their borders. Several of the agricultural experiment stations are preparing to undertake seed testing, but their equipment is limited and the number of samples handled is small. At present there are no Federal restrictions on the importation of low-grade and worthless seed. As a natural result the United States has become the dumping ground for the poor seed of Canada and Europe.

ANALYSES OF IMPORTED LOW-GRADE SEEDS.

RED CLOVER.

Table I gives the analyses of sixty-one lots of low-grade red clover seed imported during the fiscal year ended June 30, 1906, amounting to 990,809 pounds. The total importations of red clover seed for the same period amounted to 7,498,287 pounds, so that the low-grade seed furnished about one-eighth of the total. These low-grade importations contained seed enough to sow approximately 125,000 acres at an average rate of seeding. This seed is for the most part small-sized, light-weight screenings. A practical failure must be expected whenever seed of this quality is used, either from not securing a stand on account of poor germination or from smothering with introduced weeds.

TABLE I.—*Analyses of 61 samples of low-grade red clover seed imported during the year ended June 30, 1906.*

Number of seed sample.	Red clover seed.	Other seeds.	Dirt and broken seed.	Dodder present.[a]	Kinds of weed seeds.	Weight of 1,000 red clover seeds.	Germination of red clover seed.	Quantity imported.[b]	Price per 100 pounds at which seed was imported.	Live red clover seed (seed that germinated) in sample.	Actual cost of 100 pounds of red clover seed that germinated.
	Per cent.	*Per cent.*	*Per cent.*		*Number.*	*Milligrams.*	*Per cent.*	*Pounds.*		*Per cent.*	
2945......	48.06	25.78	26.16	No....	39	882	38	6,740	$5.20	18.26	$28.48
2946......	66.1	13.16	20.74	Yes...	27	900	91	5,027	7.60	60.15	12.63
2947......	77.43	9.44	13.13	Yes...	32	1,135	83	6,876	9.10	64.27	14.16
3101......	72.5	25.73	1.77	No....	10	1,594	96.5	3,750	11.00	69.96	15.72
3159......	73.14	10.38	16.48	Yes...	25	893	88.5	16,535	8.00	64.73	12.36
3222......	73.8	7.88	18.32	Yes...	24	810	89	13,380	7.20	65.68	10.96
3395......	70.41	10.90	18.69	Yes...	20	779	76.5	30,857	7.00	53.86	12.99
3400......	75.78	9.35	14.87	Yes...	28	895	80	32,706	7.75	60.62	12.78
3425......	70.05	21.89	8.06	No....	33	1,377	77.5	32,630	8.00	54.29	14.73
3432......	74.39	15.02	10.59	Yes...	50	951	75.5	22,000	8.00	56.16	14.24
3456......	43.03	19.31	37.66	Yes...	39	855	28.5	25,300	2.80	12.26	22.84
3457......	46.24	19.09	34.67	Yes...	32	818	27.5	35,347	6.10	12.72	47.95
3488......	63.31	23.22	13.47	No....	29	913	68	35,350	5.80	43.05	13.47
3566......	69.81	12.25	17.94	Yes...	23	847	72	32,893	7.50	50.26	14.92
3571......	67.89	16.67	15.44	No....	29	995	66.5	29,490	9.20	45.15	20.37
3587......	67.55	13.50	18.95	Yes...	45	898	60.5	7,015	7.10	40.87	17.37
3588......	76.74	14.53	8.73	Yes...	39	952	63.5	12,498	7.60	48.73	15.59
3591......	70.6	12.59	16.81	Yes...	30	839	21.5	13,119	3.50	15.18	16.27
3598......	74.73	12.68	12.59	Yes...	40	1,102	75.5	33,069	8.25	56.42	14.62
3647......	64.84	11.69	23.47	Yes...	32	885	68	32,562	7.70	44.09	17.46
3696......	64.09	13.79	22.12	Yes...	36	840	62.5	44,029	11.50	40.05	28.71
3721......	72.55	20.67	6.78	No....	19	1,143	75.5	32,523	7.60	54.77	13.88
3755......	65.65	18.48	15.87	No....	33	885	52.5	6,550	5.50	34.47	15.96
3810......	65.52	19.23	15.25	Yes...	23	977	48.5	15,588	6.40	31.78	20.14

[a] 75.41 per cent of samples contained dodder.
[b] Total quantity of low-grade red clover seed imported, 990,809 pounds.

FIG. 1.—ALFALFA OF GOOD QUALITY.
Natural size and magnified 9 times.

FIG. 2.—IMPORTED ALFALFA OF LOW GRADE.
Natural size and magnified 9 times.

FIG. 3.—RED CLOVER OF GOOD QUALITY.
Natural size and magnified 9 times.

FIG. 4.—IMPORTED RED CLOVER OF LOW GRADE.
Natural size and magnified 9 times.

TABLE I.—*Analyses of 61 samples of low-grade red clover seed imported during the year ended June 30, 1906*—Continued.

Number of seed sample.	Red clover seed.	Other seeds.	Dirt and broken seed.	Dodder present.	Kinds of weed seeds.	Weight of 1,000 red clover seeds.	Germination of red clover seed.	Quantity imported.	Price per 100 pounds at which seed was imported.	Live red clover seed (seed that germinated) in sample.	Actual cost of 100 pounds of red clover seed that germinated.
	Per cent.	*Per cent.*	*Per cent.*		*Number.*	*Milligrams.*	*Per cent.*	*Pounds.*		*Per cent.*	
3811......	57.3	22.81	19.89	Yes...	45	1,021	42	15,506	$5.60	24.06	$23.27
3816......	64.58	10.27	25.15	Yes...	31	886	60.5	32,116	7.62	39.07	19.50
3834......	77.45	7.70	14.85	Yes...	28	1,087	66	33,159	9.60	51.12	18.78
3906......	61.34	15.51	23.15	Yes...	45	846	53	32,468	7.50	32.51	23.07
3945......	67.04	17.10	15.86	Yes...	36	891	67	12,474	8.50	44.91	18.93
3946......	83.54	6.60	9.86	Yes...	21	995	74	30,427	11.20	61.82	18.12
3959......	94.04	.95	5.01	Yes...	12	1,357	44.5	1,576	9.50	41.85	22.70
3960......	94.15	1.77	4.08	Yes...	19	1,552	69	11,288	9.90	64.96	15.24
3962......	97.15	.66	2.19	Yes...	11	1,538	34	12,000	8.60	33.03	26.04
3963......	96.07	1.66	2.27	Yes...	14	1,585	70	6,393	8.00	67.25	11.90
3964......	96.32	1.93	1.75	Yes...	11	1,603	72	5,952	9.10	69.35	13.12
3965......	93.54	.27	6.19	Yes...	9	1,422	15	2,425	4.50	14.03	32.07
3967......	95.04	1.20	3.76	Yes...	17	1,404	48	7,937	7.60	45.62	16.66
3994......	47.49	32.08	20.43	Yes...	41	909	17.5	10,995	4.70	8.31	56.56
3990......	83.07	10.32	6.61	No....	17	1,252	72.5	750	12.00	60.22	19.93
4009......	83.87	8.02	8.31	Yes...	42	1,370	46.5	11,130	8.20	38.9	21.08
4010......	64.04	17.07	18.89	Yes...	41	835	26	15,024	5.80	16.65	34.83
4026......	68.59	17.78	13.63	Yes...	20	870	86.5	4,000	14.20	59.33	23.93
4029......	94.23	2.59	3.18	No....	11	1,582	65.5	10,318	8.80	61.72	14.25
4031......	95.41	1.76	2.83	Yes...	11	1,495	54.5	2,500	8.98	51.99	17.27
4032......	93.82	3.91	2.27	No....	14	1,732	43.5	6,303	6.80	40.81	16.66
4035......	95.52	2.16	2.32	Yes...	19	1,555	27.5	3,382	7.80	26.27	29.69
4038......	95.63	1.12	3.25	Yes...	17	1,397	53.5	2,372	7.70	51.16	15.05
4044......	67.80	14.91	17.29	Yes...	43	963	31.5	32,074	7.00	21.36	32.77
4051......	98.29	.41	1.3	No....	5	1,597	59.5	2,551	6.90	58.48	11.79
4053......	93.55	.17	6.28	Yes...	8	1,434	8	1,102	4.50	7.48	60.16
4067......	78.61	8.82	12.57	No....	15	1,164	50	453	4.00	39.30	10.18
4084......	61.09	16.93	21.98	No....	19	1,236	75.5	33,866	10.10	46.12	21.90
4097......	64.77	16.41	18.82	Yes...	50	951	46	10,787	7.00	29.79	23.50
4118......	74.04	15.18	10.78	Yes...	35	1,010	60.5	2,963	7.50	44.79	16.74
4163......	76.62	12.36	11.02	No....	26	1,165	75.5	30,000	8.10	57.84	14.00
4165......	54.44	24.57	20.99	No....	37	868	38	18,200	6.00	20.68	29.01
4179......	61.56	15.58	22.86	Yes...	48	926	55.5	22,046	6.12	34.16	17.93
4180......	61.04	12.58	26.38	Yes...	27	926	75.5	4,851	7.70	46.08	16.71
4181......	58.02	17.13	24.85	Yes...	46	933	54	22,046	6.12	31.34	19.54
4183......	77.65	8.15	14.20	Yes...	38	980	87.5	7,363	9.75	67.94	14.35
4225......	72.70	16.88	10.33	Yes...	43	1,010	29	6,178	6.00	21.11	28.42
Average.	74.06	12.17	13.83		29.7	1,105.5	58.03	....	7.61	43.16	20.39

In more than one-half of the sixty-one samples of which an analysis is given the weight of 1,000 seeds is less than a gram, while 1,000 good plump seeds weigh 1½ grams or more. These lots contain an average of only 43.1 per cent of live red clover seed and much of the seed that will germinate is worthless for seeding purposes, as it is of small size, immature, and of low vigor.

It is often claimed that seed of this kind is imported to be recleaned before it is put on the market. This, however, can not be the case, as in the importations referred to the average cost of the red clover seed that will grow is $20.39 per hundred pounds on the basis of the average import price of $7.61 per hundred pounds. At the time this seed was imported five lots of high-grade seed were offered for sale to the Department of Agriculture at an average price of $15.05 per hundred pounds, the average cost of the red clover seed that germinated being $15.59 per hundred pounds. In other words, one

hundred pounds of seed that would grow of the best quality cost $15.59, while one hundred pounds that would grow of the poorest quality was imported at a cost of $20.39.

This low-grade seed always carries a large number of weed seeds, fifty kinds being found in each of two lots. Of that from Germany all but five lots contained dodder seed.

In sowing seed of the average quality shown in Table I at the rate of 8 pounds to the acre there would be about nine weed seeds sown per square foot, including three dodder seeds to every 2 square feet.

Below is given the number of each kind of weed seeds found in the lots an analysis of which is given in Table I.

NUMBER OF WEED SEEDS TO THE POUND IN SIXTY-ONE SAMPLES OF LOW-GRADE RED CLOVER SEED IMPORTED DURING THE YEAR ENDED JUNE 30, 1906.

Sample No. 2945.—Black-seeded plantain, 95,580; lady's-thumb, 1,530; knotweed, 90; spurge, 1,440; mayweed, 450; catmint, 180; green foxtail, 4,320; yellow foxtail, 450; buckhorn, 1,890; bracted plantain, 540; chickweed, 270; curled dock, 1,260; bitter dock, 540; sorrel, 810; healall, 540; peppergrass, 360; wild carrot, 360; small crab-grass, 6,480; crab-grass, 5,670; slender paspalum, 1,350; pennyroyal, 2,700; stink-grass, 90; yellow trefoil, 540; five-finger, 180; barnyard grass, 90; spiny sida, 90; sedge, 90; three-seeded mercury, 270; vervain, 720; tumbling amaranth, 1,620; rough pigweed, 900; lamb's-quarters, 1,080; witch-grass, 7,470; spreading panicum, 990; prickly lettuce, 90; other weed seeds, 3,420.

Total weed seeds to the pound, 144,450.

Sample No. 2946.—Buckhorn, 16,200; clover dodder, 38,160; wild carrot, 5,256; healall, 4,608; low hop-clover, 648; plantain, 72; sorrel, 2,808; yellow trefoil, 144; wild chicory, 432; vervain, 432; field camomile, 360; mayweed, 72; woodrush, 72; mouse-ear chickweed, 72; lamb's-quarters, 72; hawkweed picris, 72; round-leaved toad-flax, 72; small-flowered crane's-bill, 216; bird's-foot trefoil, 72; other weed seeds, 1,728.

Total weed seeds to the pound, 71,568.

Sample No. 2947.—Buckhorn, 13,860; black-seeded plantain, 3,150; bracted plantain, 90; plantain, 90; yellow trefoil, 540; clover dodder, 3,600; Chilean clover dodder, 540; wild carrot, 3,060; sorrel, 1,350; curled dock, 270; vervain, 1,080; white vervain, 180; green foxtail, 810; lamb's-quarters, 810; healall, 630; bird's-foot trefoil, 360; hop-clover, 360; low hop-clover, 90; wild chicory, 270; kidney vetch, 90; witch-grass, 180; knotweed, 180; lady's-thumb, 90; small crab-grass, 90; ox-tongue, 90; spurry, 90; alfilaria, 90; other weed seeds, 810.

Total weed seeds to the pound, 32,850.

Sample No. 3101.—Green foxtail, 96,135; witch-grass, 1,020; plantain, 595; lamb's-quarters, 425; yellow trefoil, 595; small crab-grass, 255; lady's-thumb, 170; three-seeded mercury, 85; ragweed, 85; other weed seeds, 340.

Total weed seeds to the pound, 99,705.

Sample No. 3159.—Buckhorn, 24,130; Chilean clover dodder, 14,250; sorrel, 3,910; wild carrot, 3,910; healall, 3,825; yellow trefoil, 850; bird's-foot trefoil, 425; lamb's-quarters, 340; wild chicory, 340; ox-tongue, 340; green foxtail, 170; mayweed, 170; field camomile, 170; hop-clover, 170; mouse-ear chickweed, 85; small crab-grass, 85; low hop-clover, 170; chickweed, 85; kidney vetch, 85; red pimpernel, 85; small-flowered crane's-bill, 85; saltbush, 85; other weed seeds, 595.

Total weed seeds to the pound, 54,360.

Sample No. 3222.—Buckhorn, 93,678; clover dodder, 15,132; healall, 6,084; wild carrot, 3,276; sorrel, 2,652; yellow trefoil, 1,716; black-seeded plantain, 546; lamb's-quarters, 390; curled dock, 390; spurry, 390; bird's-foot trefoil, 312; vervain, 312; hop-clover, 234; saltbush, 156; lesser starwort, 156; mayweed, 156; white vervain, 78; chickweed, 78; ox-eye daisy, 78; green foxtail, 78; blue field madder, 78; peppergrass, 78; other weed seeds, 468.

Total weed seeds to the pound, 126,516.

Sample No. 3395.—Buckhorn, 13,940; clover dodder, 25,415; healall, 9,180; wild carrot, 5,015; sorrel, 5,490; yellow trefoil, 1,360; lamb's-quarters, 765; black-seeded plantain, 765; spurry, 425; hop-clover, 340; vervain, 255; curled dock, 255; rabbit's-foot clover, 170; wild chicory, 170; mayweed, 170; red pimpernel, 85; bird's-foot trefoil, 85; green foxtail, 85; other weed seeds, 595.

Total weed seeds to the pound, 64,565.

Sample No. 3400.—Buckhorn, 5,780; clover dodder, 8,364; sorrel, 7,790; healall, 4,592; yellow trefoil, 1,886; wild carrot, 1,558; lamb's-quarters, 656; field dodder, 410; red pimpernel, 328; hop-clover, 328; lesser starwort, 164; woodrush, 164; low hop-clover, 164; rabbit's-foot clover, 82; chickweed, 82; bitter dock, 82; small-seeded false flax, 82; vervain, 82; other weed seeds, 3,526.

Total weed seeds to the pound, 36,120.

Sample No. 3425.—Catchfly, 14,790; green foxtail, 5,780; sorrel, 4,674; buckhorn, 3,444; yellow trefoil, 3,198; curled dock, 3,280; plantain, 2,214; black-seeded plantain, 1,066; lamb's-quarters, 1,066; mayweed, 820; Canada thistle, 820; small crab-grass, 738; witch-grass, 410; mouse-ear chickweed, 410; lady's-thumb, 246; healall, 246; catmint, 164; evening primrose, 164; five-finger, 164; field cress, 164; stick-tight, 164; ragweed, 82; yellow foxtail, 164; chickweed, 82; other weed seeds, 492.

Total weed seeds to the pound, 44,842.

Sample No. 3432.—Buckhorn, 21,074; black-seeded plantain, 10,168; clover dodder, 11,316; wild carrot, 5,002; healall, 1,558; sorrel, 1,230; lamb's-quarters, 820; witch-grass, 656; yellow trefoil, 574; spreading panicum, 328; crab-grass, 410; small crab-grass, 492; chicory, 410; low hop-clover, 328; curled dock, 246; ragweed, 246; spurge, 164; mouse-ear chickweed, 164; bracted plantain, 82; forget-me-not, 82; catmint, 82; plantain, 82; barnyard grass, 82; five-finger, 82; small-seeded false flax, 82; Canada thistle, 82; red pimpernel, 246; hawkweed picris, 82; chickweed, 82; lesser starwort, 82; peppergrass, 82; bird's-foot trefoil, 82; scentless camomile, 82; other weed seeds, 1,558.

Total weed seeds to the pound, 58,138.

Sample No. 3456.—Buckhorn, 36,982; wild carrot, 36,326; yellow trefoil, 2,050; wild chicory, 4,264; clover dodder, 4,592; field dodder, 656; vervain, 2,542; healall, 1,968; low hop-clover, 82; sorrel, 984; curled dock, 410; hawkweed picris, 820; ox-tongue, 656; field camomile, 656; lamb's-quarters, 574; red pimpernel, 492; green foxtail, 410; black-seeded plantain, 164; lesser starwort, 164; Canada thistle, 82; nipplewort, 82; cat's-ear, 82; knotweed, 82; barnyard grass, 82; small crab-grass, 82; other weed seeds, 2,296.

Total weed seeds to the pound, 97,580.

Sample No. 3457.—Buckhorn, 35,700; wild carrot, 32,725; chicory, 4,845; clover dodder, 4,760; healall, 3,230; yellow trefoil, 1,785; sorrel, 1,105; lamb's-quarters, 850; green foxtail, 425; red pimpernel, 425; dodder, 425; field camomile, 340; ox-tongue, 340; curled dock, 340; hawkweed picris, 255; knotweed, 255; cut-leaved crane's-bill, 170; nipplewort, 170; black-seeded plantain, 170; mayweed, 85; lesser starwort, 85; bracted plantain, 85; spiny sow thistle, 85; other weed seeds, 5,015.

Total weed seeds to the pound, 93,070.

Sample No. 3488.—Buckhorn, 6,314; sorrel, 3,936; green foxtail, 3,198; curled dock, 2,050; lamb's-quarters, 1,640; black-seeded plantain, 1,476; plantain, 984; bitter dock, 820; catmint, 1,148; lesser starwort, 656; Canada thistle, 656; mouse-ear

chickweed, 574; mayweed, 902; lady's-thumb, 410; yellow trefoil, 328; small crab-grass, 246; stick-tight, 328; three-seeded mercury, 164; barnyard grass, 246; yellow foxtail, 164; knotweed, 82; healall, 82; witch-grass, 82; other weed seeds, 1,804.

Total weed seeds to the pound, 28,290.

Sample No. 3566.—Buckhorn, 19,890; clover dodder, 13,050; sorrel, 8,460; healall, 3,600; wild carrot, 3,420; yellow trefoil, 1,530; rabbit's-foot clover, 1,260; green foxtail, 990; low hop-clover, 630; black-seeded plantain, 450; spurry, 270; wild chicory, 270; hop-clover, 180; chickweed, 180; lesser starwort, 90; blue field madder, 90; Canada thistle, 90; small crab-grass, 90; mayweed, 90; field camomile, 90; other weed seeds, 6,300.

Total weed seeds to the pound, 61,020.

Sample No. 3571.—Green foxtail, 5,100; black-seeded plantain, 7,225; buckhorn, 3,910; plantain, 1,955; lamb's-quarters, 3,145; curled dock, 1,275; sorrel, 1,615; yellow trefoil, 2,805; witch-grass, 1,785; barnyard grass, 170; mayweed, 850; small crab-grass, 510; Canada thistle, 255; lady's-thumb, 170; mouse-ear chickweed, 170; small-seeded false flax, 85; catmint, 85; healall, 85; other weed seeds, 1,700.

Total weed seeds to the pound, 32,895.

Sample No. 3587.—Buckhorn, 23,322; wild carrot, 11,856; clover dodder, 14,742; healall, 3,042; sorrel, 2,028; lamb's-quarters, 1,560; yellow trefoil, 1,482; wild chicory, 1,248; plantain, 546; green foxtail, 468; rabbit's-foot clover, 390; low hop-clover, 312; curled dock, 312; mayweed, 234; red pimpernel, 234; evening primrose, 156; scentless camomile, 156; dove's-foot crane's-bill, 156; saltbush, 156; vervain, 3,198; small crab-grass, 156; five-finger, 156; field camomile, 156; lady's-thumb, 78; black-seeded plantain, 78; stick-tight, 78; kidney vetch, 78; frenchweed, 78; spurry, 78; ox-tongue, 78; witch-grass, 78; other weed seeds, 4,134.

Total weed seeds to the pound, 70,824.

Sample No. 3588.—Buckhorn, 24,055; dodder, 6,205; sorrel, 6,120; black-seeded plantain, 4,505; wild carrot, 2,720; healall, 2,805; lamb's-quarters, 1,615; yellow trefoil, 1,275; field camomile, 340; spurge, 510; small crab-grass, 595; low hop-clover, 425; green foxtail, 425; wild chicory, 340; bird's-foot trefoil, 340; crab-grass, 170; bracted plantain, 170; mayweed, 255; lady's-thumb, 170; lesser starwort, 85; yellow foxtail, 85; witch-grass, 85; five-finger, 85; spurry, 85; rabbit's-foot clover, 85; large-seeded false flax, 85; other weed seeds, 3,400.

Total weed seeds to the pound, 57,035.

Sample No. 3591.—Sorrel, 15,215; wild carrot, 10,710; lamb's-quarters, 9,945; buckhorn, 7,905; yellow trefoil, 4,565; healall, 2,975; catchfly, 2,295; curled dock, 2,040; black-seeded plantain, 1,785; green foxtail, 1,615; dodder, 850; kidney vetch, 510; saltbush, 425; red pimpernel, 340; small crab-grass, 340; slender paspalum, 255; wild chicory, 255; mayweed, 255; field camomile, 170; chickweed, 170; frenchweed, 170; spurry, 85; catmint, 85; lady's-thumb, 85; small-flowered crane's-bill, 85; other weed seeds, 1,020.

Total weed seeds to the pound, 64,150.

Sample No. 3598. Sorrel, 56,706; buckhorn, 14,820; clover dodder, 18,876; wild carrot, 5,070; yellow trefoil, 2,106; healall, 1,326; lamb's-quarters, 624; green foxtail, 546; plantain, 468; wild chicory, 468; small crab-grass, 234; scentless camomile, 234; forget-me-not, 234; lesser starwort, 156; mouse-ear chickweed, 156; low hop-clover, 156; knotweed, 156; ox-eye daisy, 156; rabbit's-foot clover, 78; bird's-foot trefoil, 78; woodrush, 156; red pimpernel, 78; blue field madder, 78; cut-leaved crane's-bill, 78; saltbush, 78; field camomile, 312; other weed seeds, 1,092.

Total weed seeds to the pound, 104,520.

Sample No. 3647.—Buckhorn, 11,872; clover dodder, 25,424; sorrel, 6,608; healall, 4,592; wild carrot, 4,144; yellow trefoil, 2,352; lamb's-quarters, 784; vervain, 560; low hop-clover, 448; green foxtail, 336; small crab-grass, 336; lesser starwort, 336; red pimpernel, 336; chickweed, 224; spurry, 224; curled dock, 112; lady's-thumb, 112;

hop-clover, 112; mayweed, 112; field camomile, 112; small-seeded false flax, 112; other weed seeds, 3,584.

Total weed seeds to the pound, 62,832.

Sample No. 3696.—Yellow trefoil, 2,542; clover dodder, 29,520; buckhorn, 12,218; wild carrot, 8,528; low hop-clover, 984; hop-clover, 410; healall, 5,330; sorrel, 7,626; curled dock, 164; lamb's-quarters, 2,132; vervain, 1,066; red pimpernel, 574; lesser starwort, 574; green foxtail, 574; mayweed, 246; field camomile, 246; wild chicory, 164; kidney vetch, 164; bird's-foot trefoil, 164; spurry, 164; barnyard grass, 82; small crab-grass, 82; blue field madder, 82; wood rush, 82; other weed seeds, 3,444.

Total weed seeds to the pound, 77,162.

Sample No. 3721.—Buckhorn, 7,735; green foxtail, 4,250; sorrel, 2,380; curled dock, 2,210; lamb's-quarters, 1,615; plantain, 1,445; bitter dock, 1,275; black-seeded plantain, 850; yellow trefoil, 765; catmint, 595; Canada thistle, 425; lady's-thumb, 340; mouse-ear chickweed, 255; small crab-grass, 255; knotweed, 170; mayweed, 170; other weed seeds, 2,125.

Total weed seeds to the pound, 26,860.

Sample No. 3755.—Green foxtail, 3,740; buckhorn, 3,400; black-seeded plantain, 2,720; sorrel, 2,720; lamb's-quarters, 2,125; catmint, 1,700; curled dock, 1,615; Canada thistle, 1,190; black-seeded plantain, 1,275; yellow trefoil, 595; lady's-thumb, 510; witch-grass, 340; barnyard grass, 340; lesser starwort, 255; mouse-ear chickweed, 255; mayweed, 255; small crab-grass, 255; ragweed, 255; stick-tight, 170; ox-eye daisy, 170; chickweed, 85; wild chicory, 85; yellow foxtail, 85; three-seeded mercury, 85; small-seeded false flax, 85; other weed seeds, 2,890.

Total weed seeds to the pound, 27,200.

Sample No. 3810.—Buckhorn, 7,020; dodder, 6,930; lamb's-quarters, 4,950; green foxtail, 3,420; healall, 2,790; sorrel, 3,060; wild carrot, 2,430; yellow trefoil, 810; saltbush, 1,080; red pimpernel, 900; mayweed, 270; field camomile, 180; vervain, 90; wild chicory, 90; low hop-clover, 90; rabbit's-foot clover, 90; hop-clover, 90; bird's-foot trefoil, 90; lesser starwort, 90; sweet clover, 90; other weed seeds, 1,980.

Total weed seeds to the pound, 36,540.

Sample No. 3811.—Clover dodder, 18,700; buckhorn, 19,380; lamb's-quarters, 5,355; green foxtail, 4,080; sorrel, 3,315; wild carrot, 3,060; healall, 2,550; yellow trefoil, 1,360; saltbush, 1,190; wild chicory, 680; red pimpernel, 425; rabbit's-foot clover, 340; white campion, 170; ox-tongue, 170; hawkweed picris, 85; early winter cress, 170; Canada thistle, 85; mayweed, 85; field camomile, 85; bitter dock, 85; curled dock, 85; lady's-thumb, 85; knotweed, 85; kidney vetch, 85; chickweed, 85; sweet clover, 85; black-seeded plantain, 85; mallow, 85; spurry, 85; stick-tight, 85; blue field madder, 85; other weed seeds, 2,635.

Total weed seeds to the pound, 64,940.

Sample No. 3816.—Buckhorn, 13,104; clover dodder, 6,240; wild carrot, 5,304; sorrel, 4,914; healall, 4,758; yellow trefoil, 2,574; lamb's-quarters, 1,170; green foxtail, 546; kidney vetch, 468; low hop-clover, 312; round-leaf toad flax, 234; curled dock, 234; lesser starwort, 234; chickweed, 78; ox-tongue, 156; black-seeded plantain, 156; plantain, 78; forget-me-not, 78; wood rush, 78; small crab-grass, 78; bull thistle, 78; bird's-foot trefoil, 78; other weed seeds, 3,900.

Total weed seeds to the pound, 44,850.

Sample No. 3834.—Clover dodder, 7,055; field dodder, 680; buckhorn, 7,820; sorrel, 6,205; healall, 4,420; wild carrot, 2,975; lamb's-quarters, 2,125; yellow trefoil, 1,190; green foxtail, 425; curled dock, 255; rabbit's-foot clover, 170; bird's-foot trefoil, 170; small-flowered crane's-bill, 170; chickweed, 170; yellow foxtail, 85; black-seeded plantain, 85: ox-tongue, 85; forget-me-not, 85; other weed seeds, 3,145.

Total weed seeds to the pound, 37,315.

Sample No. 3906.—Buckhorn, 14,305; clover dodder, 28,475; sorrel, 6,375; wild carrot, 6,375; healall, 6,375; lamb's-quarters, 3,145; yellow trefoil, 3,060; green fox-

tail, 2,295; black-seeded plantain, 1,275; low hop-clover, 935; rabbit's-foot clover, 850; red pimpernel, 680; curled dock, 680; mayweed, 425; bird's-foot trefoil, 340; kidney vetch, 340; hop-clover, 255; witch-grass, 170; ox-tongue, 170; lesser starwort, 170; round-leaved toad flax, 170; small-flowered crane's-bill, 85; ragweed, 85; spurry, 85; small crab-grass, 85; lady's-thumb, 85; sweet clover, 85; nipplewort, 85; other weed seeds, 4,845.

Total weed seeds to the pound, 82,305.

Sample No. 3945.—Buckhorn. 22,050; clover dodder, 6,570; healall, 3,960; green foxtail, 2,430; wild carrot, 2,430; lamb's-quarters, 2,340; yellow trefoil, 1,980; sorrel, 1,350; bird's-foot trefoil, 540; red pimpernel, 540; ox-tongue, 90; vervain, 270; small crab-grass, 180; low hop-clover, 90; lady's-thumb, 90; slender paspalum, 90; curled dock, 90; wild chicory, 90; field camomile, 90; hawkweed picris, 90; mayweed, 90; hop-clover, 90; other weed seeds, 2,430.

Total weed seeds to the pound, 47,970.

Sample No. 3946.—Buckhorn, 14,400; yellow trefoil, 3,570; healall, 1,615; clover dodder, 1,445; kidney vetch, 935; green foxtail, 850; lamb's-quarters, 1,020; sorrel, 850; wild carrot, 255; rabbit's-foot clover, 170; bird's-foot trefoil, 170; round-leaved toad flax, 85; ox-tongue, 85; bur clover, 85; small-flowered crane's-bill, 85; other weed seeds, 1,020.

Total weed seeds to the pound, 26,640.

Sample No. 3959.—Sorrel, 680; lamb's-quarters, 425; sweet clover, 425; green foxtail, 85; wild carrot, 85; yellow trefoil, 85; dodder, 85; lesser starwort, 85; rabbit's-foot clover, 85; other weed seeds, 595.

Total weed seeds to the pound, 2,635.

Sample No. 3960.—Buckhorn, 1,700; lamb's-quarters, 1,190; clover dodder, 850; yellow trefoil, 595; low hop-clover, 510; wild carrot, 340; green foxtail, 340; yellow foxtail, 255; blueweed, 170; rabbit's-foot clover, 170; sorrel, 170; healall, 85; sweet clover, 85; field camomile, 85; scentless camomile, 85; small-seeded false flax, 85; other weed seeds, 425.

Total weed seeds to the pound, 7,140.

Sample No. 3962.—Dodder, 1,190; buckhorn, 425; lamb's-quarters, 255; sweet clover, 510; low hop-clover, 85; curled dock, 85; yellow trefoil, 85; blueweed, 85; kidney vetch, 85; other weed seeds, 510.

Total weed seeds to the pound, 3,315.

Sample No. 3963.—Buckhorn, 2,028; wild carrot, 546; sorrel, 390; clover dodder, 936; field camomile, 156; yellow foxtail, 78; wild chicory, 78; healall, 78; lamb's-quarters, 390; other weed seeds, 702.

Total weed seeds to the pound, 5,382.

Sample No. 3964.—Buckhorn, 3,690; sorrel, 1,722; clover dodder, 1,066; lamb's-quarters, 246; lesser starwort, 82; yellow foxtail, 82; healall, 82; forget-me-not, 82; other weed seeds, 574.

Total weed seeds to the pound, 7,626.

Sample No. 3965.—Low hop-clover, 170; lamb's-quarters, 170; buckhorn, 85; healall, 85; wild carrot, 85; forget-me-not, 85; blueweed, 85; dodder, 85; chickweed, 85.

Total weed seeds to the pound, 935.

Sample No. 3967.—Lamb's-quarters, 1,615; buckhorn, 1,020; dodder, 850; yellow trefoil, 340; wild carrot, 255; sweet clover, 170; rabbit's-foot clover, 170; forget-me-not, 85; red pimpernel, 85; field camomile, 85; sorrel, 85; other weed seeds, 850.

Total weed seeds to the pound, 5,610.

Sample No. 3990.—Green foxtail, 20,060; curled dock, 4,590; bitter dock, 170; lamb's-quarters, 5,440; buckhorn, 680; yellow trefoil, 850; lady's-thumb, 425; sticktight, 255; sorrel, 170; mayweed, 170; Canada thistle, 170; ragweed, 170; barnyard grass, 85; other weed seeds, 850.

Total weed seeds to the pound, 34,085.

Sample No. 3994.—Plantain, 26,814; mouse-ear chickweed, 12,300; five-finger, 3,608; buckhorn, 2,788; lamb's-quarters, 3,115; sorrel, 2,378; curled dock, 2,132; shepherd's-purse, 1,804; black-seeded plantain, 1,722; mayweed, 1,722; small crab-grass, 738; yellow trefoil, 656; lady's-thumb, 492; stick-tight, 410; witch-grass, 410; wormseed mustard, 328; peppergrass, 328; barnyard grass, 246; yellow foxtail, 82; evening primrose, 82; spiny sow thistle, 82; sedge, 82; catmint, 82; clover dodder, 82; knotweed, 82; three-seeded mercury, 82; green foxtail, 5,740; Canada thistle, 904; small-seeded false flax, 82; clover dodder, 82; other weed seeds, 4,018.

Total weed seeds to the pound, 73,473.

Sample No. 4009.—Buckhorn, 12,948; wild chicory, 1,968; yellow trefoil, 2,460; wild carrot, 1,640; hop-clover, 82; rabbit's-foot clover, 82; clover dodder, 820; Chilean clover dodder, 164; green foxtail, 984; yellow foxtail, 246; healall, 820; saltbush, 738; lamb's-quarters, 656; kidney vetch, 492; black-seeded plantain, 82; bracted plantain, 82; plantain, 82; barnyard grass, 328; sorrel, 410; curled dock, 328; knotweed, 246; field camomile, 246; mayweed, 82; sweet clover, 164; ragweed, 164; red pimpernel, 164; Canada thistle, 82; cut-leaved crane's-bill, 82; bird's-foot trefoil, 82; nippelwort, 82; sticktight, 82; other weed seeds, 2,788.

Total weed seeds to the pound, 29,676.

Sample No. 4010.—Buckhorn, 23,375; sorrel, 11,730; clover dodder, 11,815; healall, 6,460; yellow trefoil, 4,675; lamb's-quarters, 2,465; wild carrot, 1,105; red pimpernel, 1,190; low hop-clover, 1,105; rabbit's-foot clover, 1,105; mouse-ear chickweed, 1,360; lesser starwort, 935; hop-clover, 935; vervain, 850; chickweed, 255; spurry, 255; kidney vetch, 255; green foxtail, 255; mayweed, 170; field camomile, 85; forget-me-not, 85; small-flowered crane's-bill, 85; bur clover, 85; black-seeded plantain, 85; plantain, 85; other weed-seeds, 8,330.

Total weed seeds to the pound, 79,135.

Sample No. 4026.—Buckhorn, 60,210; green foxtail, 6,390; ox-tongue, 6,930; wild carrot, 5,950; clover dodder, 3,570; yellow trefoil, 3,315; red pimpernel, 2,040; healall, 1,955; bird's-foot trefoil, 1,785; ox-tongue, 1,445; round-leaved toad flax, 1,190; wild chicory, 340; hawkweed picris, 255; mayweed, 85; other weed seeds, 1,275.

Total weed seeds to the pound 96,735.

Sample No. 4029.—Yellow trefoil, 5,220; buckhorn, 1,615; sorrel, 1,360; lamb's-quarters, 595; healall, 85; yellow foxtail, 85; other weed seeds, 510.

Total weed seeds to the pound, 9,470.

Sample No. 4031.—Clover dodder, 11,730; sorrel, 765; lamb's-quarters, 680; wild carrot, 595; healall, 510; black-seeded plantain, 255; buckhorn, 255; curled dock, 85; five-finger, 85; other weed seeds, 170.

Total weed seeds to the pound, 15,130.

Sample No. 4032.—Lamb's-quarters, 20,418; lady's-thumb, 410; cleavers, 656; curled dock, 410; saltbush, 246; stick-tight, 246; small-seeded false flax, 164; yellow trefoil, 164; sorrel, 82; other weed seeds, 574.

Total weed seeds to the pound, 23,370.

Sample No. 4035.—Lamb's-quarters, 5,304; buckhorn, 936; clover dodder, 780; sorrel, 546; rabbit's-foot clover, 156; yellow trefoil, 234; wild carrot, 156; blueweed, 156; green foxtail, 78; spurry, 78; bird's-foot trefoil, 78; other weed seeds, 3,822.

Total weed seeds to the pound, 12,324.

Sample No. 4038.—Clover dodder, 1,170; lamb's-quarters, 2,880; wild carrot, 360; scentless camomile, 270; wild chicory, 180; mayweed, 90; healall, 90; red pimpernel, 90; plantain, 90; sorrel, 90; hop-clover, 90; other weed seeds, 540.

Total weed seeds to the pound, 5,940.

Sample No. 4044.—Buckhorn, 12,710; clover dodder, 18,204; wild carrot, 6,630; sorrel, 2,865; healall, 3,910; yellow trefoil, 3,230; lamb's-quarters, 2,465; green foxtail, 1,615; curled dock, 1,530; round-leaved toad flax, 1,105; red pimpernel, 1,020; black-seeded plantain, 680; hop-clover, 595; low hop-clover, 510; spurry, 340; lesser star-

wort, 340; mayweed, 255; field camomile, 170; small crab-grass, 170; kidney vetch, 255; yellow foxtail, 85, stick-tight, 85; wild chicory, 85; lady's-thumb, 85; ox-tongue, 85; chickweed, 85; other weed seeds, 5,100.

Total weed seeds to the pound, 64,209.

Sample No. 4051.—Sorrel, 2,720; lamb's-quarters, 340; rabbit's-foot clover, 340; black-seeded plantain, 255; knotweed, 85.

Total weed seeds to the pound, 3,740.

Sample No. 4053.—Low hop-clover, 85; buckhorn, 170; field camomile, 170; clover dodder, 85; healall, 85; other weed seeds, 425.

Total weed seeds to the pound, 1,020.

Sample No. 4067.—Buckhorn, 15,030; green foxtail, 8,100; black-seeded plantain, 7,650; barnyard grass, 630; yellow foxtail, 540; three-seeded mercury, 540; knotweed, 270; lady's-thumb, 270; plantain, 270; five-finger, 180; yellow trefoil, 90; lamb's-quarters, 90; curled dock, 90; witch-grass, 90; other weed seeds, 360.

Total weed seeds to the pound, 34,200.

Sample No. 4084.—Lady's-thumb, 10,030; plantain, 20,740; mouse-ear chickweed, 17,000; curled dock, 3,230; shepherd's-purse, 2,975; yellow trefoil, 1,785; lamb's-quarters, 1,700; five-finger, 1,615; green foxtail, 935; black-seeded plantain, 850; Canada thistle, 680; spiny sow thistle, 255; yellow foxtail, 170; knotweed, 85; other weed seeds, 340.

Total weed seeds to the pound, 62,390.

Sample No. 4097.—Buckhorn, 16,405; clover dodder, 24,820; wild carrot, 6,290; sorrel, 6,205; healall, 6,035; yellow trefoil, 3,910; green foxtail, 3,485; lamb's-quarters, 3,400; kidney vetch, 1,020; vervain, 935; red pimpernel, 850; black-seeded plantain, 595; low hop-clover, 510; mayweed, 510; curled dock, 510; rabbit's-foot clover, 425; lesser starwort, 240; ox-tongue, 255; saltbush, 255; field camomile, 170; wild chicory, 170; lady's-thumb, 170; small crab-grass, 170; blue field madder, 85; slender paspalum 85; ragweed, 85; small-flowered crane's-bill, 85; hedge mustard, 85; hop-clover, 85; sweet clover, 85; other weed seeds, 7,395.

Total weed seeds to the pound, 85,325.

Sample No. 4118.—Yellow trefoil, 20,790; buckhorn, 20,610; healall, 3,510; wild carrot, 3,150; clover dodder, 2,970; sorrel, 2,160; catchfly, 1,080; lamb's-quarters, 990; field camomile, 900; red pimpernel, 540; kidney vetch, 270; green foxtail, 180; scentless camomile, 180; chickweed, 180; small-flowered crane's-bill, 180; Canada thistle, 90; wild chicory, 90; lady's-thumb, 90; lesser starwort, 90; cut-leaved crane's-bill, 90; blue field madder, 90; field dodder, 90; other weed seeds, 1,980.

Total weed seeds to the pound, 60,300.

Sample No. 4163.—Buckhorn, 4,410; plantain, 3,825; green foxtail, 3,655; mayweed, 1,870; black-seeded plantain, 1,530; curled dock, 765; five-finger, 425; catmint, 340; sorrel, 340; lady's-thumb, 340; Canada thistle, 340; ragweed, 255; mouse-ear chickweed, 170; barnyard grass, 170; yellow trefoil, 170; wild basil, 170; yellow foxtail, 85; wormseed mustard, 85; small crab-grass, 85; other weed seeds, 2,635.

Total weed seeds to the pound, 21,665.

Sample No. 4165.—Black-seeded plantain, 93,585; green foxtail, 6,035; small crab-grass, 7,055; crab-grass, 4,760; witch-grass, 4,845; buckhorn, 2,720; curled dock, 2,380; lady's-thumb, 1,785; pennyroyal, 1,445; lamb's-quarters, 1,360; bracted plantain, 1,445; spurge, 1,275; yellow foxtail, 1,105; spreading panicum, 595; sorrel, 850; pepper-grass, 340; evening primrose, 255; mayweed, 255; yellow trefoil, 255; slender paspalum, 170; barnyard grass, 170; spiny sida, 170; wild carrot, 170; catmint, 85; three-seeded mercury, 85; other weed seeds, 4,080.

Total weed seeds to the pound, 137,275.

Sample No. 4179.—Buckhorn, 20,202; clover dodder, 35,802; wild carrot, 5,772; lamb's-quarters, 5,070; sorrel, 5,070; yellow trefoil, 2,886; healall, 3,822; low hop-clover, 1,092; green foxtail, 1,014; red pimpernel, 624; dodder, 468; vervain, 546;

rabbit's-foot clover, 468; oxtongue, 390; hop-clover, 312; curled dock, 234; saltbush, 234: field camomile, 234; mayweed, 156; wild chicory, 156; black-seeded plantain, 156; nettle-leaved goosefoot, 78; forget-me-not, 78; mouse-ear chickweed, 78; lady's-thumb, 78; scentless camomile, 312; plantain, 78; chickweed, 78; lesser starwort, 234; kidney vetch, 78; other weed seeds, 3,822.

Total weed seeds to the pound, 91,422.

Sample No. 4180.—Buckhorn, 27,716; clover dodder, 35,670; low hop-clover, 1,445; rabbit's-foot clover, 255; wild carrot, 3,400; sorrel, 3,485; yellow trefoil, 3,145; healall, 2,890; lamb's-quarters, 2,720; field camomile, 765; red pimpernel, 595; green foxtail, 510; wild chicory, 425; lesser starwort, 340; chickweed, 85; nipplewort, 85; Canada thistle, 85; forget-me-not, 85; small-flowered crane's-bill, 85; bird's-foot trefoil, 85; small-seeded false flax, 85; other weed seeds, 3,145.

Total weed seeds to the pound, 77,101.

Sample No. 4181.—Buckhorn, 21,690; clover dodder, 46,980; sorrel, 7,565; wild carrot, 5,780; lamb's-quarters, 4,760; healall, 4,335; yellow trefoil, 2,465; green foxtail, 1,360; lesser starwort, 935; red pimpernel, 850; scentless camomile, 765; low hop-clover, 765; round-leaved toad flax, 595; rabbit's-foot clover, 510; black-seeded plantain, 595; field camomile, 340; kidney vetch, 340; wild chicory, 340; spurry, 255; chickweed, 170; ox-tongue, 170; forget-me-not, 170; saltbush, 170; hop-clover, 170; ox-eye daisy, 170; yarrow, 85; plantain, 85; mayweed, 85; curled dock, 85; other weed seeds, 5,440.

Total weed seeds to the pound, 90,025.

Sample No. 4183.—Buckhorn, 9,540; clover dodder, 8,460; lamb's-quarters, 6,210; green foxtail, 4,320; oxtongue, 1,710; round-leaved toad flax, 1,800; yellow trefoil, 1,260; red pimpernel, 900; low hop-clover, 810; wild carrot, 540; sorrel, 360; hawkweed picris, 360; healall, 180; large-seeded false flax, 180; mayweed, 180; forget-me-not, 180; rabbit's-foot clover, 90; spurry, 90; witch grass, 90; field camomile, 90; small-seeded false flax, 90; field cress, 90; horehound, 90; Frenchweed, 90; bull thistle, 90; other weed seeds, 3,510.

Total weed seeds to the pound, 41,310.

Sample No. 4225.—Buckhorn, 26,910; Chilean dodder, 5,940; wild carrot, 9,360; sorrel, 7,560; catchfly, 7,380; healall, 6,390; clover dodder, 6,210; lamb's-quarters, 3,600; yellow trefoil, 2,610; small-flowered crane's-bill, 900; lesser starwort, 810; red pimpernel, 630; green foxtail, 630; spurry, 540; mayweed, 540; small crab-grass, 450; kidney vetch, 360; bird's-foot trefoil, 270; plantain, 270; blue field madder, 180; forget-me-not, 180; yellow foxtail, 180; oxeye daisy, 90; scentless camomile, 90; curled dock, 90; spurge, 90; slender paspalum, 90; chickweed, 90; hop clover, 90; low hop-clover, 90; other weed seeds, 5,760.

Total weed seeds to the pound, 88,380.

In Table II are given the analyses of the five samples of high-grade red clover offered for sale at an average price of $15.05 per hundred pounds, previously referred to.

TABLE II.—*Analyses of five samples of high-grade red clover seed offered for sale during the year ended June 30, 1906.*

Number of seed sample.	Red clover seed.	Other seeds.	Dirt and broken seed.	Dodder present.	Kinds of weed seeds.	Weight of 1,000 red clover seeds.	Germination of red clover seed.	Price per 100 pounds at which seed was offered for sale.	Live red clover seed (seed that germinated) in sample.	Actual cost of 100 pounds of red clover seed that germinated.
	Per cent.	*Per cent.*	*Per cent.*		*Number.*	*Milligrams.*	*Per cent.*		*Per cent.*	
36668	96.59	1.44	1.97	No	7	1,705	100	$15.00	96.59	$15.53
37427	98.54	.28	1.18	No	2	1,501	98.5	14.00	97.06	14.42
37440	98.42	.93	.65	No	7	1,531	97.5	14.75	95.96	15.37
37442	97.00	1.27	1.73	No	7	1,678	100	16.00	97.00	16.49
37443	98.10	.35	1.55	No	3	1,486	98	15.50	96.14	16.12
Average	97.73	.85	1.42	....	5.2	1,580	98.8	15.05	96.55	15.58

The accompanying diagram presents in graphic form a comparison of the averages of the analyses of red clover seed imported, as shown in Tables I and II.

ALFALFA.

Table III gives the analyses of sixteen selected low-grade samples of imported alfalfa seed, representing cargoes amounting to 275,572 pounds. Since the total importations of alfalfa seed during the same period were 5,688,689 pounds, the low-grade seed furnished about one-twentieth of the total. The quality of this low-grade seed is similar to that of the red clover seed shown in Table I. The germination is low and the seed in many samples is small or shriveled. All but two of these lots contain dodder, and all contained on an average more than fifteen kinds of weed seeds.

TABLE III.—*Analyses of sixteen samples of low-grade alfalfa seed imported during the fiscal year ended June 30, 1906.*

Number of seed sample.	Alfalfa seed.	Other seeds.	Dirt and broken seed.	Dodder present.[a]	Kinds of weed seeds.	Weight of 1,000 alfalfa seeds.	Germination of alfalfa seed.	Quantity of seed imported.[b]	Price per 100 pounds at which seed was imported.	Live alfalfa seed (seed that germinated) in sample.	Actual cost of 100 pounds of alfalfa seed that germinated.
	Per cent.	*Per cent.*	*Per cent.*		*Number.*	*Milligrams.*	*Per cent.*	*Pounds*		*Per cent.*	
2929	84.56	3.52	11.92	Yes	18	1,704	79.5	10,208	$9.50	67.22	$14.13
2941	96.18	1.28	2.54	No	1	2,166	46	12,106	8.10	44.24	18.30
2942	88.58	1.98	9.44	Yes	14	1,890	53	7,797	7.90	46.95	16.83
2996	89.42	3.68	6.9	No	10	1,787	56.5	16,475	9.25	50.52	18.31
3002	88.06	3.24	8.7	No	12	1,866	52.5	32,439	9.40	46.23	20.33
3003	87.8	3.54	8.66	No	12	1,748	45	15,923	9.90	39.5	25.06
3047	90.46	3.97	5.57	Yes	14	1,757	58	16,610	10.25	52.47	19.53
3068	94.38	2.59	3.03	Yes	9	1,834	50	14,475	8.50	47.19	18.01
3082	91.01	4.33	4.66	Yes	15	1,622	63.5	16,632	10.25	57.79	17.73
3158	90.8	4.68	4.52	Yes	18	1,328	9	33,275	2.00	8.17	22.22
3393	94.63	1.77	3.6	Yes	17	1,753	73.5	16,500	10.13	69.55	14.56
3751	87.4	2.1	10.5	Yes	20	1,529	8	33,022	2.63	6.99	37.55
4132	82.02	6.18	11.8	Yes	23	1,032	77	5,610	7.50	63.15	11.87
4135	72.54	14.13	13.33	Yes	22	1,065	50	11,396	6.00	36.27	16.54
4232	63.85	16.79	19.36	Yes	26	1,037	58.5	3,844	5.00	37.35	13.39
4267	81.31	4.38	14.31	Yes	21	1,164	43.5	29,261	5.70	35.37	16.12
Average	86.44	4.89	8.68	......	15.75	1,580	51.47	....	7.63	44.31	18.78

[a] 75 per cent of the samples contained dodder.

[b] Total quantity of low-grade alfalfa seed imported, 275,572 pounds.

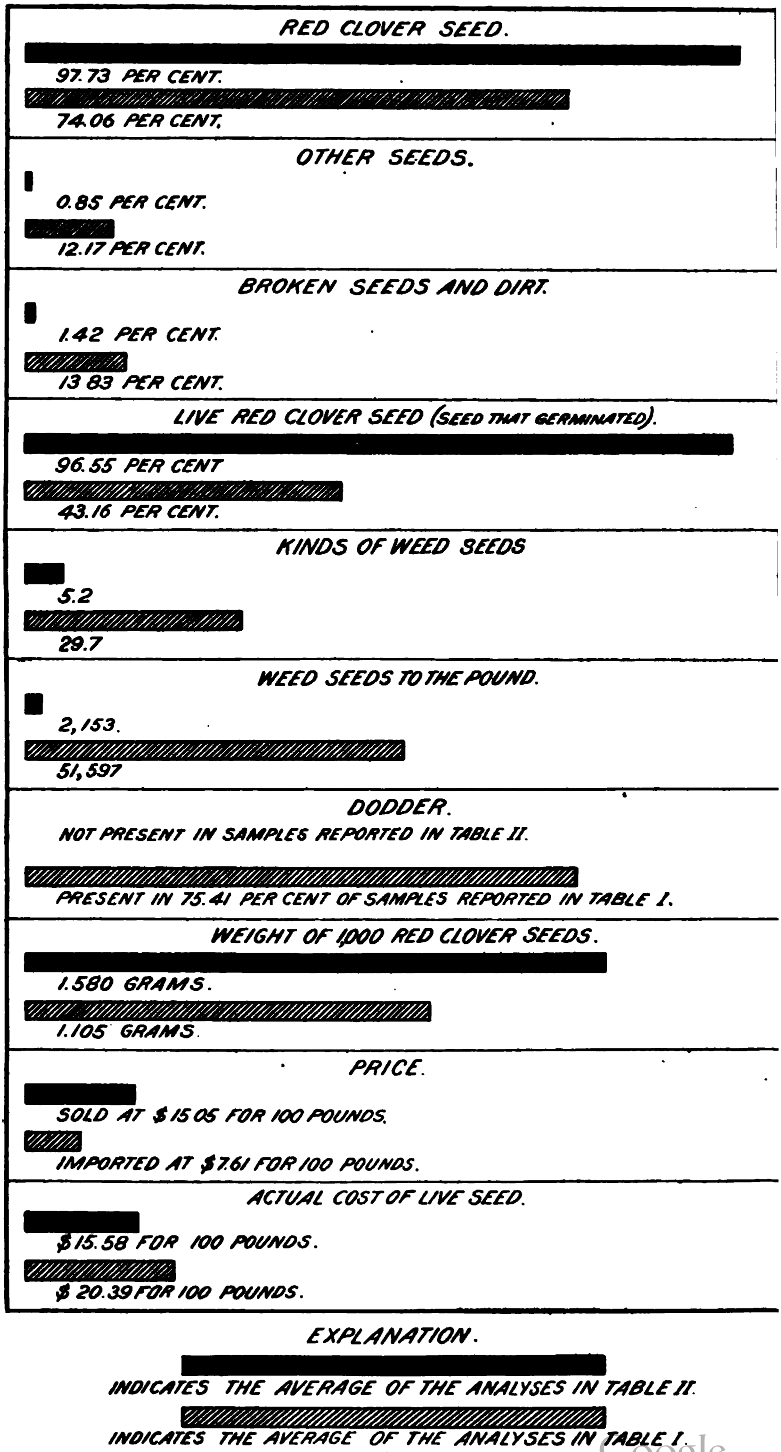

FIG. 1.—High-grade red clover seed compared with low-grade red clover seed: Averages of analyses shown in Table II (high-grade) and Table I (low-grade).

THE IMPORTATION OF LOW-GRADE SEED SHOULD BE STOPPED.

Every pound of worthless seed imported is finally sold to the farmer. Some of it goes into the trade to fill the demand for cheap seed. More of it is used to mix with better seed in the grading-down process. By mixing 100 pounds of seed worth $15 with 100 pounds of imported screenings which cost $7.50, a medium grade will result, costing $11.25 per hundred pounds, which is not sold at $11.25 but at $13 or $14 per hundred pounds. Whenever a dealer mixes two qualities of seed together to make a medium or low grade the price is not reduced in proportion to the quality. In this way the jobber or dealer who mixes seeds invariably gets a profit on the screenings which are used.

Unfortunately many farmers in the United States furnish a ready market for the refuse from our own cleaning mills, and moreover, on account of their demand for cheap seed, we are importing the waste from other countries. Seedsmen should not, perhaps, be altogether blamed for meeting this demand for cheap seed, and they must be expected to sell it as long as there is a call for it. At the same time, the farmer not being as good a judge as the seedsman often takes what is offered at the lowest price and unwittingly pays more for the seed that will grow than if he had bought the best. What is of more importance to the farmer, however, is not that he is paying more for his seed than he should, but that in buying low-grade seed he gets either a poor stand from sowing dead seed, or small, weak plants from sowing seed of low vigor, or the crop is smothered by weeds which will continue to foul the land for many years.

Argentina has a law prohibiting the importation of alfalfa and clover seed containing the seed of dodder. Canada prohibits the sale within her borders of seed containing weed seeds, but provides for its export. Europe is effectually protected from the use of poor seeds through its seed-control stations, but its screenings are exported. It seems time that the United States had some restriction on the importation of seeds of such poor quality that they can not be sold in other countries.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 111, PART IV.

B. T. GALLOWAY, *Chief of Bureau.*

FORAGE CROPS FOR HOGS IN KANSAS AND OKLAHOMA.

BY

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FORAGE CROPS FOR HOGS IN KANSAS AND OKLAHOMA.

INTRODUCTION.

Farmers are more and more realizing that pasture is necessary for the most economical production of pork. Those who are raising hogs and putting them on the market with the least cost have their entire farms fenced hog tight. This enables them to give the hogs the range of the meadows and fields when the crops have been harvested. Much that would otherwise be lost is thus saved by the hogs, for they are among the best gleaners of the waste grain, weeds, and insects in the fields.

More hog pastures are fenced each year, more experimenting is being done, and there is more inquiry as to the best crops for pasture. These questions can not be answered intelligently without a knowledge of the conditions of soil and climate, the market, and the adaptability of crops to different sections of the country.

The Office of Farm Management Investigations has undertaken to ascertain by a study of farm practice: (1) What crops have been found best for pasture for hogs in different localities; (2) the season during which these crops are available; (3) the number of stock they will pasture to the acre; (4) the value of this pasture in connection with other feeds; (5) the quantity of grain necessary to produce a given amount of pork on different pastures; and (6) the cost of producing pork.

While only a small beginning has been made, the demand for such knowledge and its importance to the swine industry of the country has prompted the publishing of this information for each locality as it is obtained.

CROPS USED IN KANSAS AND OKLAHOMA.

During the past summer (1907) about 150 of the most successful swine growers and pork producers of Kansas and Oklahoma were interviewed on the subject of the crops used for feed. In southern

Oklahoma along the river valleys and in northern Oklahoma and southern Kansas the farmers are favored with a soil and climate that make it possible to produce pork very cheaply. The mildness of the climate makes it unnecessary to build as expensive shelters for hogs in winter as are required farther north, and the open and short winters make it possible to furnish pasture during a greater portion of the year, thus lessening the amount of grain which it is necessary to feed. The main pasture crops for hogs in this region are alfalfa, wheat, oats, and rye, ranking in importance in the order named.

ALFALFA.

It is the testimony of 95 per cent of the farmers interviewed in this region that there is no better pasture for hogs than alfalfa, where it can be grown successfully. Those who have failed with it as pasture owe their failure to two causes. First, the alfalfa has been pastured before it has become well rooted. Young alfalfa is too tender a plant to stand severe treatment except under very favorable circumstances. There are a few farmers who have pastured it the same year it was sown and the alfalfa has survived, but this was on rich, heavy loam soil, usually creek bottom or river valley land with water not far below the surface, and the season was very favorable. Ordinarily alfalfa should not be pastured until the second year, and better still not until the third year if it is desired to keep the field as permanent pasture.

The second cause of failure with alfalfa is heavy pasturing and lack of judgment in pasturing in unfavorable seasons. A good many farmers have sown a small piece of alfalfa, and then because it has grown rapidly and all kinds of stock are fond of it they have turned all the stock on the farm on it and have wondered why their alfalfa was killed out. Others pasture regardless of whether the ground is muddy or whether the season is dry and hot. In either case heavy pasturing is very likely to cause the alfalfa to be killed out.

ALFALFA PASTURES.

As to the amount of pasturage or the number of hogs alfalfa will carry per acre without injury to the crop, the estimates given by farmers vary considerably, depending on the kind of soil, the fertility of the land, and the size of the hogs pastured. The following, however, is a safe average estimate as given by conservative men who have had much experience. River valley and creek bottom land well set in alfalfa will carry from 15 to 20 head per acre of 50 to 125

pound hogs. Upland of fair average fertility will support from 8 to 10 head of the same kind of hogs. There are fields that have supported 25 head per acre all through the season for a number of years and are still in good condition, and there are other fields that will not furnish pasture for more than 5 head per acre; but these are extremes. When a field is used only for pasture it is better to divide it into several lots and move the hogs from one to the other as occasion requires.

The length of the season during which this pasture is furnished also varies. Alfalfa is ready for pasture on the average from the middle of April in southern Oklahoma to the middle of May in northern Kansas. In many cases it will do to pasture earlier, but it is not best, as the young alfalfa has not the start it should have for heavy pasturing, nor has it the strength in the plant. When not pastured too early it will furnish feed at the rate mentioned during nearly the whole season until October in the North and November in the South. In some years the pasture season will continue a month later in the autumn, depending on the rainfall and the lateness of cool weather. In some seasons, if the summer is unusually dry and hot, the pasture will become short; but usually pasture for the number of hogs previously specified can be depended on for about seven months of the year in the southern limit of the territory named and for about five months in the northern limit. This rule will apply to other sections of the country in the same latitude as Oklahoma and Kansas.

While many farmers pasture alfalfa fields to their full capacity, in some sections, especially in northern Kansas, it is customary to run about half as many hogs as the alfalfa fields will support. This practice permits the cutting of the usual number of crops of hay, though the yield of hay is, of course, reduced.

Alfalfa not only furnishes a great amount of pasture, but it is of a character that goes to make bone and muscle. It belongs to the leguminous family of plants, as do the clovers, the cowpea, the field pea, the soy bean, and the vetches, and while it is furnishing this valuable food it is at the same time adding fertility to the land. Alfalfa pasture or alfalfa hay and corn are very nearly a balanced ration for animals, and while it is better to have a grain ration fed with it to hogs as well as other animals, yet a healthier, thriftier hog can be raised on alfalfa alone than on corn alone. Many instances are found where hogs have been raised on alfalfa alone. One Oklahoma farmer marketed in December, 1905, 61 head of spring pigs eight months old that averaged 171 pounds. These hogs had run from the time they were little pigs with their mothers on 15 acres of

alfalfa without any grain. They sold on the market for 5½ cents a pound. This made the cash value of the alfalfa pasture about $38.35 per acre. As will be seen, this is light pasturing, as there were only about 4 pigs per acre besides the brood sows.

As already stated, it is much better economy to furnish a grain ration with the pasture, as it results in better gains and a better product. One man estimates that it takes from one-half to one-third less corn on alfalfa pasture than on a straight grain ration to make a hog ready for market. Many let the hogs run on alfalfa until about five to six months old, by which time they reach a weight of 75 to 125 pounds, feeding just a little grain; then they feed heavily for about two months and sell the hogs at eight months old weighing 200 to 225 pounds. One farmer, who raises about a thousand hogs a year and who in one year sold $11,200 worth of hogs, makes a practice of growing his hogs on alfalfa pasture until about eight months old, feeding one ear of corn per head daily. He then feeds heavily on corn for a month or two and sells at an average weight of 200 to 225 pounds. Another man feeds all the corn and slop the pigs will clean up, all the while running them on alfalfa pasture, and sells at six to eight months old at weights of 250 to 300 pounds. Another, who raises about a thousand head a year, feeds all the corn the pigs will eat, beginning shortly after weaning and continuing until the hogs are sold at ten to eleven months old, averaging about 275 pounds.

Still another farmer, from weaning time (two months old) until eight months old, feeds the pigs nothing but dry corn on alfalfa pasture, averaging about one-half gallon of corn (3½ pounds) a day per head. At the end of eight months he sells at an average weight of 250 pounds. Feeding the above quantity of corn a day makes the amount fed about 11¼ bushels per head. Figuring this at the average price of corn in this locality, 35 cents, and the price received for pork, 5½ cents, the following results will show the cost of growing pork on this farm and the value of alfalfa pasture:

Value of 250-pound hog, at 5½ cents	$13.75
Value of pig at weaning, 50 pounds, at 5½ cents	2.75
Gain from pasture and grain	11.00
Cost of 11¼ bushels of corn, at 35 cents	3.93
Value of pasture per head pastured	7.07

Now, compare these results with those of a man who had to depend on other pasture crops than alfalfa. He estimates that it will take 15 bushels of corn on wheat, oats, and rye pasture to raise and fatten a hog so it will weigh 240 pounds at nine months old, besides the pasture and slop. At the price of corn mentioned, 35 cents a bushel,

and with hogs at 5½ cents a pound, note the cost of producing pork on this farm:

Value of 240-pound hog, at 5½ cents	$13.20
Value of pig at weaning, 50 pounds, at 5½ cents	2.75
Gain from pasture and grain	10.45
Cost of 15 bushels of corn, at 35 cents	5.25
Value of pasture per head pastured	5.20

The pasture specified here will not support more than half as many head per acre on this farm by feeding corn all the time. The value of this pasture is only $5.20 per head, against $7.07 per head for alfalfa pasture on the other farm.

The experiences of these men are sufficient to show the value of alfalfa pasture alone, and its greater value when grain is fed in connection, and that it is an important factor in economic pork production. A little later in this bulletin will be given the feeding systems of some farmers which will still further show the excellence of this forage crop and others and the cost of producing pork under such systems.

ALFALFA HAY.

While alfalfa pasture has been found to be very valuable for hogs, the hay as a part ration for winter is scarcely less important. Throughout the region referred to the farmers are feeding the hay to hogs in winter. Many feed the hay by throwing it on the ground in forkfuls; others have made low racks in which the hay is placed, where the hogs can feed like cattle or sheep. The hay has been found to be especially valuable for brood sows before farrowing. Where it is fed during the winter only a small grain ration is necessary to keep the sows in good flesh and in healthy condition. Sows thus fed also farrow good litters of strong, healthy pigs.

The hay is usually fed dry. The leaves are more readily eaten by the hogs than the stems, as they contain more of the nutritive value of the plant. For this reason some farmers save the last cutting of hay for the hogs because it is more relished. It is eaten up cleaner, as the stems are not so woody, and more food value is found in the leaves. Sometimes the hay is cut up fine, wet, and mixed with other feed, and sometimes it is fed ground, as there are now alfalfa mills scattered throughout the alfalfa regions. But it is very doubtful whether this extra expense will pay, unless it be for a ration for young pigs.

To avoid the expense of cutting or grinding, some farmers in order to get the hay all eaten have soaked it in water and fed it. This has proved very satisfactory where tried. One Oklahoma farmer carried his hogs through a winter by feeding them alfalfa leaves soaked in hot water for one day and the next day shorts mixed with the pulp and water. He feeds much alfalfa hay to his hogs and is very successful with them. He puts the last cutting in shock as soon as wilted, and thus cures it without bleaching and feeds it to his hogs. Another farmer carried his entire herd of hogs through the winter by feeding them the pulp of alfalfa hay after soaking it in water over night. He also gave them the water to drink. This was all the feed they had during the winter, and they were in good flesh in the spring, with smooth glossy coats of hair. A Kansas farmer was feeding a bunch of 50 fall pigs on corn; during the winter they got off feed and were not thrifty. He reduced the corn and gave a ration of two-thirds chopped alfalfa hay and one-third corn meal, the two soaked together. The hogs began to do better, and a little later he changed the ration to one-third alfalfa and two-thirds corn. The results were very satisfactory, and the cost of feed was reduced from $15 a month on corn to $9 a month on alfalfa and corn. So alfalfa hay, as well as pasture, has a very important use on a hog farm.

WHEAT.

In northern Oklahoma and southern Kansas fall wheat is a staple crop. It is generally seeded from the middle of September to the first of October. The seeding is usually $1\frac{1}{4}$ to $1\frac{1}{2}$ bushels per acre. If the ground has been well prepared and the fall is not too dry, this will have made a good growth by the time alfalfa pasture is beginning to fail, along in November. The season here usually remains open until Christmas, so that six weeks of very good pasture are furnished. Some winters are so open that the wheat remains green most of the winter and stock find pasture all winter. The spring opens up by the last of February and the wheat gets green again in March. By judicious pasturing, not pasturing too heavily or when the ground is muddy, much green feed may be had without injury to the wheat. The farmers here have taken advantage of this, and where they have their wheat fields fenced hog tight they turn the hogs from the alfalfa field to the wheat field in November and leave them there during the winter unless the wheat gets too short or the ground becomes muddy. The hogs remain in the wheat until April and do well with very little grain. At this time they can go back to the alfalfa field again. Thus, green pasture is furnished the year round.

Where this is possible two litters a year of 200-pound hogs can be raised with profit and pork produced very cheaply.

Wheat will not carry as many hogs to the acre as alfalfa. The usual number is about six head per acre, though some farmers claim that the maximum is about ten. One man claims that hogs are one of the best animals for pasturing on wheat, not trampling it out as cattle or horses do. Another farmer of large experience thinks it is dangerous to pasture pigs at about weaning time on wheat. He has lost twice, he thinks, from that cause. The last time he saved only 15 out of 45 head. He claims that wheat is too fibrous and collects in balls in a pig's stomach and intestines, causing inflammation, from which the pig dies. It is claimed by some farmers that wheat is injurious to hogs just as it begins to shoot in spring. More information is needed on this point. The usual practice is to remove the hogs from wheat in early spring and put them on alfalfa or other summer pasture, so that experience with wheat pasture later in the season is limited.

The value of wheat as pasture lies chiefly in the fact that it furnishes green feed for the hogs at a season of the year when it is very much needed, especially by young and growing hogs. By having pasture at this season there is a great saving of grain, very little being needed. It also enables fall pigs farrowed in September to be carried through the winter in good condition, thrifty and well grown, so that by giving corn in the spring they can be sent to market by June nearly as cheaply as the March pig can be shipped by December. Quite frequently, where hogs have been grown on alfalfa or wheat pasture, they will, when put on a heavy feed of corn, make a gain of 12 to 15 pounds for every bushel fed.

OATS.

In the same region where wheat is used for pasture, oats are also used for spring pasture and are highly spoken of by all who have used them. Some claim that hogs will do better on oats than on wheat. The hogs like them better and will eat them as long as they grow, while they do not like wheat when it begins to head. In this locality many sow oats in March to furnish spring pasture for the hogs when they come off the wheat and before the alfalfa is ready to pasture. Sometimes oats are sown with rape at this time for the same purpose and to give variety to the pasture. Oats will furnish pasture at about the same rate as wheat.

The great value of oats is due to the fact that they furnish succulent feed at a season when it is much needed, giving variety to the pasture. They are also greatly relished by hogs. Oats are particu-

larly valuable as pasture for sows and young pigs, many farmers sowing them for this purpose. One farmer claims that he is less troubled with scours in pigs on oat pasture than on alfalfa.

RYE.

Rye is not so generally grown for a pasture crop in Oklahoma and Kansas as the crops just discussed. Many farmers, however, use rye to make a part of the pasture crop for their hogs, and its value can not be denied.

Rye is seeded from September 1 to the middle of October. The early seeding is best, as it comes on early and gets well established before cold weather and will thus make better fall and winter pasture. Rye is an excellent pasture for late fall, winter, and early spring. If not pastured too heavily in the spring it will head out and make a very good yield of grain. The grain is an excellent ration to feed with corn to pigs and growing hogs or to grind and mix in slop for sows with pigs.

The amount of pasture furnished by rye is about three-fourths that furnished by alfalfa, being estimated as supporting from 6 to 12 hogs per acre. One man reports having pastured 50 head of hogs on 5 acres during fall, winter, and spring, then harvesting 20 bushels of grain per acre. In the southern part of this region rye would be an excellent cover crop for the soil during the winter. Besides furnishing pasture it could be turned under as a green manure to add humus to the soil.

LESS IMPORTANT FORAGE CROPS.

While alfalfa, wheat, oats, and rye are the principal forage crops, there are others that are used to some extent. Among these are clover, rape, sorghum, cowpeas, soy beans, artichokes, and grasses.

CLOVERS.

The clovers are not generally used in the territory discussed. Among those most used for pasture crops are red clover and white clover. These are good, especially in the latitude of central Kansas and farther north, but south of this the clovers do not do so well. Red clover and white clover are the older pasture crops and are in more general use in the older sections of the country. They are both excellent forage crops for hogs. Red clover comes in well in the rotation of crops; it fertilizes the land and furnishes both pasture and hay. It is often sown with oats or barley in the spring, or later in corn after the last cultivation. It does very well with corn

where there is sufficient rainfall, but in the drier regions this method of seeding clover is not to be recommended. The first fall it is used for pasture; the second season it is used as a pasture and hay crop. It will furnish pasture for about ten head of hogs per acre during the first half of the season and half that many the last half, provided the soil is fairly good and the season not too dry. The hay is excellent for hogs, especially for brood sows in winter, but does not equal alfalfa hay.

White clover is better used in permanent pasture with some of the grasses, as Kentucky bluegrass. It will not furnish as much pasture as red clover, but is especially good while in bloom during May and June. It does better on moist ground than red clover and will do very well on some poor soils. It is not recommended to sow alone nor for hay, although the dry hay contains upward of 14 per cent of crude protein.

Alsike clover is better in some regions than red clover, especially on low, moist ground. In some localities farther north it does better and is a more certain crop. It will supply about as much pasture as red clover, is seeded at the same time, and furnishes pasture for the same period. As a hay crop it will not yield as much, but it is a little better than red clover, as it does not have as woody a stem.

Crimson clover has not succeeded well in the past in this region, but is to be recommended for further trial as a pasture crop. Along the Atlantic coast, the only region where it is largely and successfully grown, it has been found that the hairs of the blossoms are likely to gather in dense balls in the stomach and intestines of animals, especially the horse, and cause death. For this reason it should not be cut for a hay crop after the flowers mature. It is an excellent winter pasture crop for swine, however, and will furnish more pasture than red clover. It is a winter annual, and should be sown in August or September.

The chief value of crimson clover is that it acts as an excellent cover crop for soil during the winter months and prevents the soil from washing or leaching. It also furnishes in southern regions excellent winter and early spring pasture for hogs.

RAPE.

Rape is usually sown in early spring—in March or early in April—in Oklahoma and furnishes pasture by May. The Dwarf Essex variety is used. It is seeded either broadcast, at about 4 pounds of seed per acre, or else in drills 30 to 32 inches apart, using 3 pounds per acre. Drilling is the best method, as this permits of cultivation. The plants grow more rapidly and make pasture sooner. When sown in drills,

the hogs will not break down and destroy so much of the crop. Early-sown rape will furnish pasture from May until August. If rape is not grazed too closely in the spring and the stalk is not eaten off, it will grow up and make fall pasture.

A good growth of rape will supply pasture for about 15 or 20 hogs to the acre. One man claims that it will take 25 head to pasture it down.

It is often difficult to get hogs to eat rape at first if they have not been accustomed to it. For this reason it is not grown by some. Its value as a forage crop, however, is shown in the experiments of the Wisconsin Agricultural Experiment Station, where it was proved to have a feeding value per acre, when combined with a ration of corn and shorts, equivalent to 2,436 pounds of grain and a money value of $19.49 per acre. When the cost of seeding is counted, rape proves valuable for pasture, as the seed can be bought usually for 8 cents a pound and 3 to 5 pounds an acre is all that is needed. Rape should not be pastured until it is a foot high.

Considerable complaint is found with rape because it causes sores and scabs on the hogs. Sometimes the skin has the appearance of being blistered. This is especially true of white hogs. This difficulty can be remedied somewhat by removing the hogs to other pasture crops for part of the time and applying a mixture of sulphur and lard to the sores.

As one of the annual forage crops rape is valuable on account of the cheapness of the pasture, the quantity of feed furnished, the general thriftiness of the hogs on the pasture, and because it adds variety to the ration and is available at a time when other pastures may be short.

SORGHUM.

Sorghum is used quite extensively in the drier upland regions for summer pasture. It is valuable on account of the great amount of feed furnished, pasturing from 20 to 30 head of hogs per acre. It comes in as a summer pasture when other pastures are frequently short on account of hot, dry weather. It is sown in May and furnishes pasture during July, August, and September, or even later.

Sorghum is less palatable and nutritious than many other forage crops adapted to this region. For this reason many do not like it as a pasture crop. Hogs do not thrive as well on it as on alfalfa and require more grain to keep them growing nicely.

The special value of sorghum lies in the fact that it furnishes a great abundance of pasture in dry, hot weather when alfalfa makes little growth. After it is well started, say 2 feet high, it will furnish fairly good pasture for 30 hogs to the acre for a few weeks, and

a good crop will carry 25 head of 100-pound pigs nearly all summer. Generally speaking, it is used only to fill in during dry, hot weather when alfalfa is at a standstill.

COWPEAS.

Cowpeas are just beginning to be recognized in this section as having great feeding and fertilizing value. They do much toward restoring the fertility of the soil, and some farmers are making use of the vines as a forage crop for their hogs. Wherever they have been tried the farmers are enthusiastic in their praise of them. Not enough data have been obtained on pasturing to be able to say how many head of hogs cowpeas will support per acre; but in a comparison of their feeding value with corn for hogs the results obtained by the South Carolina Experiment Station show their importance. In this test 6.02 pounds of corn and 4.91 pounds of cowpeas were necessary to produce a pound of pork. One farmer in Oklahoma reported that his hogs preferred the cowpea hay to alfalfa hay. All kinds of stock are fond of the hay and do well on it.

The value of cowpeas as a forage crop lies in the fact that they furnish a food on which the hogs make good gains. The plants will make a good growth on rather poor soil and furnish feed during late summer and fall when other green crops may be short. They also bring the soil into a more productive state, the same as clover or alfalfa.

If cowpeas are planted in May they will make late summer pasture. The best pasture is obtained after the peas are formed and well grown, as the peas are very nutritious and cause the hogs to gain in flesh rapidly.

In this same latitude in the higher altitudes, as in the San Luis Valley in southern Colorado, where it is too cold for corn, the farmers have found the Canadian field pea a very profitable crop for forage both for sheep and hogs. A large acreage of these peas is put in each year, the peas being sometimes sown alone, but more frequently with oats or barley. The seeding is done in April or early in May, and the crop can be pastured by midsummer. The best season for pasturing however, is later, when the peas have formed, the stock being allowed to harvest the crop. Hogs make a very thorough harvesting, cleaning up the peas and the vines quite thoroughly. What vines are left on the ground, together with the manure, enrich the soil and add more humus to it. In addition to this the labor of harvesting is saved. Some fields, of course, are harvested for hay and make excellent winter forage for cattle, horses, and sheep. The hogs raised in this valley receive no corn. They go on the market as bacon hogs and top the market in competition with corn-fed hogs. These hogs usually get no

farther than Pueblo, Leadville, Silverton, and adjoining towns. The Pueblo packers have been using them for a number of years and speak very highly of them. Thus, the field pea has made the hog industry profitable outside of the corn belt.

SOY BEANS.

The soy bean is used but little as a forage crop by farmers in this section, and the value of this crop is but little appreciated. Soy beans can be planted on a field from which a small grain crop has been removed, and some varieties will make an excellent growth of forage and even mature seed. They will thus furnish pasture for hogs during the latter part of August and September, and the green and ripening beans when harvested by the hogs in this way make an excellent feed. The beans when fed in a ration consisting of one part beans and three to five parts of corn or Kafir corn, as shown by the Kansas Agricultural Experiment Station, make a very profitable ration for fattening hogs. The saving in the amount of feed necessary to make a gain of 100 pounds is from 13.2 to 37.5 per cent and the increase in gain is from 14.6 to 96.4 per cent. Also, in a feeding test at the Indiana Agricultural Experiment Station, where soy beans, middlings, and tankage were used as rations with corn, the soy beans proved to be the most valuable adjunct used. As compared to corn fed alone, hogs that received one-third soy beans to two-thirds corn made two and one-fifth times as much gain in the same length of time. The cost per 100 pounds of gain where corn was fed alone was $5.01 against $3.59 where one-third soy beans and two-thirds corn was fed. Hogs so fed look thrifty, have a good appetite, fatten rapidly, and have glossy hair like animals fed oil meal.

The great value of the soy bean is its power to withstand excessive drought, like Kafir corn, and it will also withstand much wet weather. It is not attacked by chinch bugs and in addition to its great feeding value makes an excellent second crop following wheat or oats to build up run-down or thin soil. Protein is very necessary in a ration for building bone and muscle, as all feeders are coming to know, and the soy bean is exceptionally rich in this. It even stands ahead of alfalfa in this respect.

GRASSES.

The grasses are not so good for hog pasture as the crops previously mentioned, but they are used to some extent. Those most commonly grown are Kentucky bluegrass, English bluegrass or meadow fescue, Bermuda grass, and the native wild grasses.

Kentucky bluegrass is used through Kansas and southern Nebraska. South of Kansas in Oklahoma Bermuda grass is used.

As an example of the value of English bluegrass, the experience of one farmer in northern Oklahoma may be cited. He uses only English bluegrass and wild grass as pasture. On 12 acres of the bluegrass sown the fall before, he pastured 150 head of stock hogs all the spring until about the middle of May. The hogs were then taken off and the grass allowed to go to seed. This farmer states that he harvested a crop of seed larger than the ordinary crop.

Bermuda grass is not much used as a pasture for hogs, but should be grown more in regions to which it is adapted. It is relatively rich in protein, is not easily killed out by pasturing, and withstands drought well. It is often used as a soil binder and might well be used for hog pasture. Many hilly farms that are now washing badly could be put in Bermuda grass and pastured to stock, thus saving the land and building up the soil. Some farmers are beginning to make use of this grass and are fencing it for hog pasture. It withstands heavy grazing, rooting, and trampling.

Some farmers have fenced in the prairie grass and are now grazing their hogs on it. While it does not have a very high feeding value, hogs will do very well on it with grain. One man claims that prairie grass will make hogs hold their own at the rate of 6 head per acre.

ROOT CROPS.

The root crops most used in this territory are potatoes, artichokes, peanuts, and sugar beets.

Artichokes are a very good root crop to use for hogs. They can be planted in the spring the same way as potatoes and cultivated the same. In the fall the hogs can be turned in to harvest them. They thus furnish a good late fall and winter food, especially for brood sows and shoats. One farmer claims that 1 acre will keep from 20 to 30 head in fine condition from October till spring. Their use reduces considerably the amount of corn that must be fed. None of the tubers need be dug except for seed; the hogs will dig the rest. Early in the fall hogs do not eat artichokes readily. In winter and spring they eat them greedily.

Artichokes have a tendency to become a pest on cultivated land, or if planted continuously on the same land they become diseased. They may be grown very successfully, however, in a pasture crop rotation for hogs. As the acreage needed is not large, they can be planted on a part of a field in March or April and the rest of the field sown to rape. In August the part sown to rape can be reseeded to rape for fall pasture. This field can be sown to oats the next spring after rape, and barley sown after the artichokes. The crop may be pastured continuously if needed, or later mowed for hay. In August, after this crop is

removed, rye and clover may be sown. This will furnish pasture for the ensuing fall and for the following year. This makes a three-year rotation of pasture crops that fit in very well with each other. Preparing the land in July and August for the following crop of rye and clover effectually eradicates the artichokes.

The Oregon Agricultural Experiment Station made a test to determine the feeding value of artichokes with grain for hogs. The result of the test showed that where artichokes were fed there was a saving of nearly 2 pounds of grain for every pound of gain in live weight. Besides, the hogs were healthy and vigorous all the time.

The artichoke is superior to the common beets and turnips for hogs—about the same as potatoes—and they are richer in protein than sweet potatoes.

Peanuts are but little used in this region, but farther south and east they are used extensively. One man estimates that when pork is 4 cents a pound, peanuts return $10 per acre when harvested by hogs.

The Alabama Agricultural Experiment Station made investigations as to the relative value of peanuts, chufas, cowpeas, rape, sorghum, and sweet potatoes as pasture crops for hogs. The amount of grain required with peanuts to make 1 pound of gain was 1.77 pounds; with chufas, 2.3 pounds; with rape, 2.68 pounds; with cowpeas, 3.07 pounds; with sweet potatoes, 3.13 pounds, and with sorghum, 3.7 pounds. Five Tamworth hogs in twenty days on Spanish peanuts gained 2.29 pounds a day each.

Peanuts can be very profitably grown in many sections of the latitude of Oklahoma and Kansas. This crop will do better on a sandy loam than on a heavy clay soil, and will make a fair crop on thin soil where corn will not yield well. They are a very good crop to raise, both for pasture and for hay; stock of all kinds are very fond of the hay. When the nuts are left on, it is richer in protein than alfalfa hay. The variety best to grow, both for hay and pasture for hogs, is the Spanish peanut. It is a small-sized nut and grows in great clusters close around the taproot of the plant. The Spanish nut is not so particular in soil requirements as the larger varieties and is easier harvested on account of growing in clusters.

It is claimed that peanuts can be grown in dry regions where corn will not succeed. This, if true, is important in the southern-plains region. Peanuts can be made to take the place of corn in fattening hogs, although the peanut-fed hog makes softer lard and the quality of the meat is not so good, especially in the bacon hog. But as an adjunct to corn the peanut is an excellent forage crop. It is claimed that the northern-grown nut is better flavored and less oily than that grown in the South.

The peanut can be planted the last of April or first of May in the latitude of the regions discussed in these pages and is ready to turn the hogs on by the last of August.

In Colorado, in the sugar-beet district, hogs have been fed quite extensively on beets in the winter. Beets do not prove satisfactory when fed alone, but are used to some extent as part ration with grain. One farmer states that he saves a good supply each year to feed in the winter to his hogs to keep them in a healthy condition.

In a feeding test at the Colorado Agricultural Experiment Station sugar beets proved to be wholly unsatisfactory when fed with grain. The cost per hundred pounds of gain of beets and barley fed hogs was $6.01; of beets and corn fed hogs, $7.22, the latter being higher than any other ration fed.

PUMPKINS.

Pumpkins are an excellent feed for keeping hogs in a healthy condition. Many farmers claim that the seeds of pumpkins will prevent worms in pigs and shoats and that a ration of pumpkins fed with grain will keep hogs thrifty and give them a good appetite. A good many wagonloads can be grown on an acre of rich land. Stumpy land or low moist land will grow good pumpkins.

PASTURE CROPS FOR DIFFERENT SEASONS.

It is not the purpose of this bulletin to discuss the rotation of crops and its importance on the farm, but the aim is to briefly mention the forage crops that are adapted for hogs each month of the year in this region and to explain how they can be made to overlap each other, so that green pasture can be provided for each month in the southern part of the territory discussed and for the greater part of the year in the northern part. Hog raisers know that some months of the year there is an abundance of pasture, while at other seasons there is very little, if any. At such times other feeds must be resorted to that will supply the deficiency. The extra feed required is expensive and cuts down the margin of profit in pork production.

It will not be practicable to name the crop that is best adapted to every locality for the different seasons, as each farmer must know his soil and conditions and adapt his crops to those conditions. The following table will show the crops that may be ready for pasture in the months specified and the possible area of pasture provided, but the choice of one or more of these must be left to the farmer himself.

TABLE I.—*Crops that may be available for pasturing hogs every month in the year, with the number of head an acre will support.*[a]

For pasture during—	In the latitude of—	Crops that may be used.	Time of sowing.	Number of hogs that can be pastured per acre.
April and May	Oklahoma	Alfalfa	Previous year	8-16
		Rye	Previous fall	6-10
		Oats	March 1	6-10
		Rape	....do	15-20
	Kansas	Alfalfa	Previous year	8-16
		Rye	Previous fall	6-10
		Clover	....do	6-10
		Oats	Last of March	6-10
		Kentucky bluegrass.		8-10
		English bluegrass	Previous fall	8-12
June and July	Oklahoma	Spring rye	March 1	6-10
		Late oats	April 15	6-10
		Sorghum	March 1 to April 1	20-30
		Alfalfa	Previous year	8-16
		Potatoes	March	(Unknown.)
	Kansas	Rape	March 1 to April 15	15-20
		Spring rye	April 1 to 15	6-10
		Late oats	April 15 to May 1	6-10
		Sorghum	April 1	20-30
		Alfalfa	Previous year	8-16
		Prairie grass		5
August and September	Oklahoma	Sorghum	April	20-30
		Cowpeas	May	10
		Soy beans	....do	13
		Peanuts	April	8-10
		Alfalfa	Previous year	5-10
	Kansas	Sorghum	May 1	20-30
		Cowpeas	....do	10
		Soy beans	....do	10
		Peanuts	....do	8-10
		Potatoes	April 1	(Unknown.)
		Alfalfa	Previous year	5-10
October and November	Oklahoma	Alfalfa	....do	7-14
		Wheat	September 15	6-8
		Rye	September 1	7-10
		Sweet potatoes	May 1	8-12
		Artichokes	March or April	15-25
		Rape[b]	....do	15-20
	Kansas	Alfalfa	Previous year	7-14
		Wheat	September 1	5-6
		Clover	March or April	6-10
		Peanuts	May 1	8-10
		Rye	September 1	5-6
		Sweet potatoes	May 1	8-10
		Artichokes	April	15-25
December and January	Oklahoma	Wheat	September 15 to October 1	5-8
		Rye	September	5-8
		Artichokes	April	15-25
	Kansas	Wheat	September 1	5-8
		Rye	....do	5-8
		Artichokes[c]	April	15-25
February and March	Oklahoma	Wheat[d]	September 15 to October 1	5
		Rye	September	6-10
		Artichokes	April	15-25
	Kansas	Rye	September 1	5-10
		Artichokes[c]	April	15-25

[a] The number of hogs that can be pastured per acre, it must be remembered, depends on the fertility of the soil, on the season, and on the size of the hogs. This estimate is based on the same figures as were secured on alfalfa pasture; i. e., hogs that weigh from 50 to 125 pounds per head.

[b] Rape will furnish fall pasture as indicated if it is not pastured too close in the spring. It will branch out from the roots and stem in the fall. It may also be planted in August for fall pasture.

[c] Artichokes are available when not frozen. They may be left in the ground until it thaws in the spring, when the hogs will finish harvesting them.

[d] Wheat should not be pastured after the 1st of April if a crop of grain is desired.

SYSTEMS OF HOG FEEDING.

Nearly every farmer who has succeeded with hogs has a feeding system of his own, yet there are some features common to all. A good illustration of the successful handling of hogs on a small farm is that employed by a man in northern Oklahoma on an 80-acre farm. He has his whole farm fenced hog-tight and turns off annually from it an average of 100 head of hogs. All these are of his own raising and are grown and fitted for market with the crops raised on his farm, with the exception that a little corn is occasionally bought. He has 5 acres of alfalfa and each autumn sows 5 acres of wheat for late fall and winter pasture. In the spring he sows oats to supplement the wheat and alfalfa. The wheat is sown at the rate of 1½ bushels to the acre, about September 1, and furnishes pasture in the fall, when alfalfa pasture is getting short, and for a part of the winter. The wheat will also furnish some pasture for the hogs in the spring. The oats tide over until the alfalfa is ready for pasture. Thus, green feed is furnished for the greater part of the year. The rest of his 80 acres this farmer plants to corn. A part of this corn is fenced off and "hogged down" in the fall. As fast as the hogs need it the fence is moved over, and fresh corn is taken in. This pasturing is begun at the same time that corn is usually cut up green and fed to hogs, i. e., when it is in the roasting-ear stage. Spring pigs are turned on this. This plan of feeding is kept up until the remainder of the corn is all husked from the field. Then the hogs are turned in to clean up the waste corn in the field. Last summer cowpeas were drilled in the corn when plowing the last time. These furnished much valuable feed in addition to the corn.

In April this man had 20 head of fall pigs averaging about 125 pounds. These shoats had had no feed except wheat and alfalfa pasture and the waste grain they gathered from the field except a little corn that was thrown to them each day in the late winter and early spring. In April they were put on ground corn for thirty days. During this time each ate an average of one-fourth bushel daily. At the end of thirty days they averaged 225 pounds. This makes an average gain of 3⅓ pounds per day, or a little more than 13 pounds of gain for each bushel of corn fed. The market price of corn was 50 cents a bushel. The hogs sold at $5.50 per hundred, thus bringing 73⅓ cents a bushel for the corn fed.

This farmer raises two litters of pigs a year, farrowed in March and September, turning off fall pigs in the spring and spring pigs in the fall, selling at 6 to 8 months old. From March 15 to November 1, 1906, he turned off $720.50 worth of hogs and had 22 head in the fattening pens, all of his own raising and all grown and fattened on the products of his own farm.

Another farm in the same locality will serve as an illustration of what may be done with fall pigs in this section. Eighty head ran on the alfalfa and wheat fields of the farm during fall and winter. They gathered roughage and waste grain in the fields and were fed no grain until 6 months old. At this age they averaged 135 pounds. They were then fed some corn on alfalfa pasture, the amount gradually increasing till the pigs were on full feed. Corn was fed for two months, during which time the pigs made an average gain of 14 pounds for every bushel of corn fed. They were sold at 8 months old, weighing 235 pounds each. The price of the corn was 45 cents a bushel. This makes the cost of the corn fed $257.14, or $3.21 for each hog. At the average price of hogs in this locality, 5½ cents, the herd averaged $12.92½ per head. Deducting the price of corn fed leaves, as the value of the fall and winter pasture for each hog, $9.71.

Another farmer ran a bunch of September pigs on alfalfa and wheat pastures until the following May, when they weighed 125 pounds. They received in addition one ear of corn each twice a day. At this time the corn was increased gradually until each hog was getting 10 ears twice a day, which this farmer claims is the maximum feed for young hogs. They were fed thus for six weeks, making in this time a gain of about 100 pounds a head and consuming 10 bushels of corn each at a cost of $3.50 a head, or 3½ cents a pound for each pound of gain on corn. Allowing 4 bushels more as the quantity probably fed up to the fattening period at two ears a day, makes the cost for corn for each hog $4.90. To this adding $1.10 a head for pasture and slop (the cost of the slop fed is not known) brings the cost of each hog to $6.50 a head, or 2⅗ cents a pound. This allowed a good margin of profit at the ruling price of pork.

To show the importance of alfalfa hay in a system of feeding, the practice of the farmers around North Platte, Nebr., and elsewhere may be mentioned. The alfalfa hay is ground up fine or else fed whole with corn in the proportion of about 5 pounds of alfalfa to 1 pound of corn. This is fed to the brood sows during the winter, and they come through in excellent condition on very cheap feed. In many sections alfalfa hay is worth about $5 a ton on the farm. One ton of alfalfa and about 8 bushels of corn will keep three brood sows one hundred and thirty days, or nearly the whole winter. The hogs so kept farrow pigs that are remarkable for their vigor and size.

In these times of scarcity of labor and its high price many farmers are trying to reduce the labor on the farm. Some of the hog raisers have adopted the plan of harvesting the corn crop by turning the hogs into the cornfield and letting them gather it, or "hogging it down," as it is called.

One man in Ohio turned 122 spring pigs and older hogs into a 10-acre cornfield in September. The total weight of the hogs was 15,693 pounds. The spring pigs averaged 82 pounds and the older hogs 156 pounds. There was about the same number of each kind. The corn would yield about 60 bushels an acre, and in it there were a good many pumpkins. The hogs had access also to a 5-acre clover field from which the seed had been removed. Water was hauled to them and they had the shade of the woods near by. In twenty-eight days the hogs had gained 6,522 pounds. At this time 57 head were sold, averaging 245 pounds, bringing $5.15 per hundred. The remainder were not sold, but the farmer was offered $5 per hundred for them. Counting the entire gain of 6,522 pounds at $5 would make $327.60, or $31.20 per acre for the field. This paid 52 cents a bushel for the corn which on the market was worth 40 cents. The whole herd of hogs made an average daily gain of 1.92 pounds.

Another man in southern Kansas makes a practice of "hogging down" corn. He uses a portable fence and fences off 5 to 10 acres at a time, taking in more as needed. He turns the hogs in the corn in August. On 12 acres of corn one year he fattened 50 head of hogs, using about 600 bushels of corn. Of the bunch 42 head were sold, averaging 240 pounds, netting $600. Allowing 100 pounds gain for each hog on the corn thus fed, the corn brought 41½ cents a bushel, without the expense of gathering.

Another man in Oklahoma has been "hogging down" corn for a number of years. About 500 head of hogs are turned off this farm every year. By gathering and weighing corn beside that which was gathered by hogs, it was found that a bushel of corn "hogged down" will make as much pork as the same quantity husked and fed, while the expense of harvesting is saved; besides saving the labor of feeding the corn to the hogs the field is also cleaned up better than a husked field.

An Iowa farmer began hogging down corn several years ago, using 20 acres the first year. He watched carefully the feeding of the hogs on this field and concluded that no more corn was wasted than would have been left in the field by the average husker. Since that time he has hogged down all his corn, thus saving the expense of husking. This man says the cost of husking for one year will fence the field hog-tight if there is already a wire fence for cattle. Husking 40 acres of corn yielding 40 bushels per acre, at 4 cents per bushel—it has cost nearer 5 cents the last season (1907), figuring board, etc.—amounts to $64. If the 40 acres are a square field this allows 20 cents a rod for the fence the first year. With a cattle fence already provided this will buy the wire to make it a good hog-tight fence. Besides this there are two other great objects to

be attained by this method of harvesting corn: (1) The improvement of the land and (2) the health of the hogs. The farmer referred to says that in his first year's experience he snapped 20 acres of corn beside the field hogged down. The next spring both were sown to small grain under the same conditions and with the same preparation. The wheat on the land where corn was hogged down made 5 and the oats 7 bushels more to the acre than did the other. The difference is just as noticeable in a succeeding corn crop. The husks, cobs, stalks, and leaves all remain on the land, and these, with the manure from the hogs, enrich the soil and add organic matter to it.

The health of the hog is another important item. Hogs that have plenty of range and exercise are not nearly as susceptible to disease as those confined in a small pen. A hog that goes out after his feed will be well grown and thrifty, accustomed to the elements and not liable to be injured by a sudden change of weather. It is difficult to put a good finish on hogs while running in a large pasture. If they are allowed to run on good pasture until three weeks or a month before sending to market, and are then shut up and given all the corn they want, with plenty of pure water, they will make very rapid gains.

This man allows his pigs to run in the corn as soon as the land is plowed the last time, but does not let the older hogs into the field until the corn is in good condition to feed in the fall. He says he has also had good results from letting cattle into the corn first and following these with hogs. He thinks this is the most practical solution of the labor problem when help is so high-priced and scarce.

As stated in the beginning, it is the aim in this bulletin to deal with some of the practical problems that are confronting the farmers of this country. Facts that have come under the writer's observation in the past year (1907) have been stated as concisely as possible and applied to the territory visited and to similar latitudes. It is impossible, as already stated, to prescribe for the wants of each individual farmer in the limits of a bulletin such as this. The facts are given in a general way, and it remains for each hog raiser to pick and choose for himself as his judgment dictates.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 111, PART V.

B. T. GALLOWAY, *Chief of Bureau.*

THE CULTURE AND USES OF BROME-GRASS.

BY

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THE CULTURE AND USES OF BROME-GRASS.

INTRODUCTION.

It is the purpose of this bulletin to describe some of the more general methods used in the growing and utilization of brome-grass in the sections where it is now of most importance, and not to discuss in complete detail its culture throughout the entire United States. While the methods described are those employed in North Dakota, South Dakota, and the Canadian Northwest, they are also applicable in general to all other sections where this grass can be grown. The treatment given the subject is slightly inconsistent, since the methods actually practiced by the farmers and the suggestions and conclusions drawn by the writer from his investigations are combined in such a way as not to make them entirely distinct. It is hoped, however, that the matter will in this form be of more assistance to those contemplating the growing of the grass than were another plan of arrangement followed.

Brome-grass (*Bromus inermis* Leyss.), sometimes called smooth brome or Hungarian brome, is a vigorous perennial grass, possessing aggressive underground rootstocks by which it propagates readily. In general, it grows from 15 to 30 inches high, but under exceptionally favorably conditions it attains a height of 4 feet or more. The seed is borne in an open panicle closely resembling that of the well-known chess, or cheat, and is produced abundantly. (See Pl. I, fig. 1.) Although the grass is inclined to mat at the base, the entire stem is also quite leafy. (See Pl. I, fig. 2.)

Brome-grass was introduced from Europe about 1880 and has attained considerable importance in North Dakota, South Dakota, and the Pacific Northwest. It is grown in this country to some extent throughout the general region from Kansas north to the Canadian boundary and west to the Pacific coast, but its importance in the timothy and clover region is at present very limited. The grass is capable of withstanding severe cold and extended periods of drought, but it is seriously affected by heat, and consequently can not be grown successfully south of the southern boundary of Kansas except at high altitudes or under otherwise favorable conditions. It does well on

a variety of soils, but gives best results on soil that is well supplied with humus. It can, however, be grown very successfully on sandy or gravelly land.

In the Dakotas and the closely adjacent sections brome-grass is of more importance than in any other portion of this country. It has been grown in this region for twelve or fifteen years, but is as yet not so widely distributed as would be expected. Improved methods of growing alfalfa, making that crop more certain, are in a measure responsible for the comparatively limited use of brome-grass. This is true more especially in South Dakota than in North Dakota. In sections where alfalfa can be grown brome-grass can not compete with it as a hay crop. In the more humid portion of the above-named States and on the better classes of soil it has the reputation of being difficult to eradicate, and, whether this is warranted or not, this belief has a decided tendency to make the grass unpopular in such sections. For the above reasons and because there is still a considerable quantity of native hay produced, and consequently not such a pressing demand for cultivated grasses, brome-grass has not attained more importance than is the case at present.

METHODS OF CULTURE.

PREPARATION OF THE SEED BED.

For the preparation of the seed bed it is the common practice to plow the ground as early as possible in the spring, which in most sections is in March or very early in April. It is then put into condition for seeding by a thorough harrowing, or by disking, harrowing, and rolling. A careful preparatory treatment is considered essential in the securing of a good stand of grass. Some successful growers favor fall plowing, since this puts the land in better condition for seeding in the spring. Brome-grass follows all crops with practically the same results. It does well after corn, as well-cultivated corn ground is usually quite free from weeds. Wheat and oats, however, are most commonly the preceding crops.

SEEDING.

The seed is usually sown during the first part of April or as soon as the weather is favorable, which may be even as early as the latter part of March. One bushel (14 pounds) to the acre is considered by most growers to be a sufficient quantity of seed to produce a satisfactory stand, and good results are often obtained with 10 to 12 pounds. At the Manitoba experimental farm 10 pounds of good seed is recommended, and 10 to 12 pounds at the Saskatchewan experimental farm.

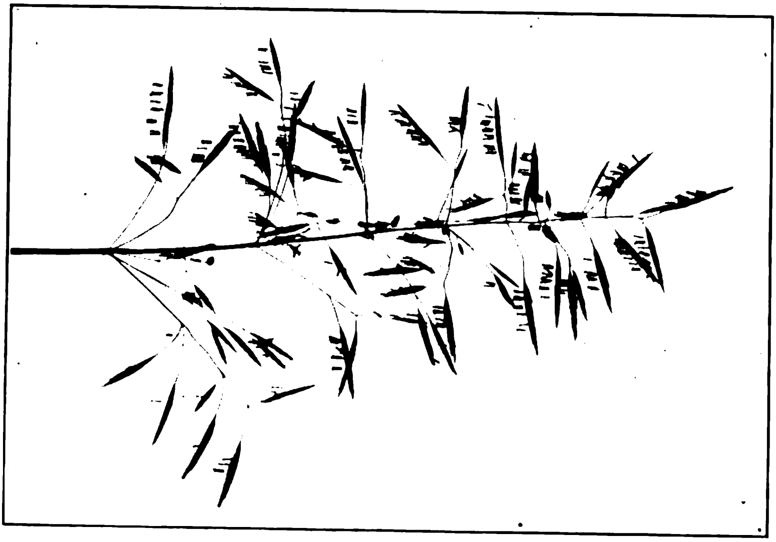


FIG. 1.—A PANICLE OF BROME-GRASS (BROMUS INERMIS) IN FULL BLOOM.

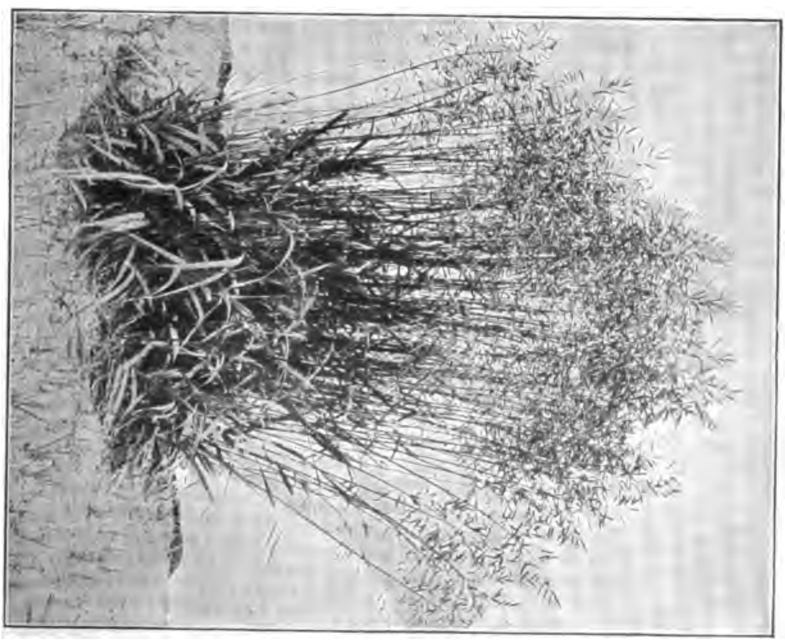


FIG. 2.—A SINGLE PLANT OF BROME-GRASS (BROMUS INERMIS).

If desired for pasture alone, it is considered well to sow as much as 20 to 25 pounds to the acre, since this quantity gives a stand that will make good grazing sooner after sowing than a light seeding. Heavy seeding is advised for sections where the grass is being introduced or is not commonly grown. The decrease in recent years in the quantity of seed sown to the acre is due to the fact that home-grown seed is used and better methods are employed in cleaning and sowing it.

The amount of rainfall in any section usually determines whether the seed is sown with or without a nurse crop. In general, in the eastern half of the Dakotas a nurse crop is used, while in the western part, where the rainfall is less, the grass is sown alone. Wheat, oats, barley, and spelt are used as nurse crops and are usually sown at the same rate as when sown alone. The grass seed is sometimes mixed with the grain, but it is a more common practice to drill in the grain, sow the grass broadcast afterwards, and cover by harrowing across the drills. In sowing brome-grass seed with grain it is often difficult to prevent it from being covered too deeply, which usually results in an uneven stand. Difficulty is also often experienced in getting a mixture of grain and grass seed to feed evenly through the drill.

Even in the more humid sections of the Dakotas there is some difference of opinion as to the advisability of using a nurse crop. The best argument in favor of this practice is that returns are obtained from land which otherwise would be practically idle for one year, as the grass yields nothing the first season, even though sown alone. Seeding alone, however, usually gives a better stand, except, perhaps, on weedy land, in which case a nurse crop is quite effective in keeping down the weeds.

In the less humid sections, where brome-grass is most commonly sown alone, the preparation of the seed bed is essentially the same as in cases where a nurse crop is used. When the seed is sown with a drill, it is a good practice to harrow afterwards, as this treatment leaves the ground in a better condition to conserve moisture. The only objection to this method is that it is likely to cover the seed too deeply.

Where fall wheat is grown, brome-grass is sometimes sown with it. By the time the wheat is cut the next summer the grass has made a good growth, and a heavy crop of hay is secured the year following this. Throughout the entire brome-grass region there is some fall seeding done, the time of seeding varying from July to October.

Whether sown in the spring or fall, with or without a nurse crop, brome-grass generally does not make a very vigorous growth and yields practically no forage or seed the first season. When sown alone it is found necessary to mow the grass once during the summer to keep down the weeds. In this case the cutting should be allowed

to remain on the ground. Aside from this, the field receives no attention and in most cases it is not pastured in the fall. When grazed during the autumn of the first year care should be taken to avoid overpasturing.

RENEWAL OF MEADOWS.

Under ordinary conditions a meadow of brome-grass will remain productive for three or four years, depending largely on the kind of soil and the nature of the treatment which it receives. Although it has been grown for a number of years in this country, there has been very little done in an experimental way by farmers to determine the best methods of renewing old meadows. In the Canadian Northwest more attention has been given to this subject, and farmers there have obtained very good results by their methods.

The history of a field of brome-grass is in general as follows: During the season in which it is seeded very little is obtained from it, except, perhaps, a small amount of pasturage; the next year a very fair crop of hay is secured; the third year, a maximum crop; the fourth year the yield is considerably reduced; and following this it decreases rapidly, owing to the meadow becoming what is commonly called "sod-bound." As before stated, the decrease in yield after the third year depends to a large extent on the kind of soil, since on heavy, rich soils the grass usually remains productive for a longer period. The character of the season also is thought to have an effect on the life of the meadow, and some farmers are of the opinion that if conditions are exceptionally favorable for a large crop the second year the grass has a tendency to diminish in yield earlier than if an ordinary crop was produced at that time.

The method of renewal giving best results in the Canadian Northwest and also practiced to some extent in the Dakotas is that of shallow breaking, the time of year depending largely on the amount of rainfall. The experimental farm at Brandon, Manitoba, recommends that the meadow be plowed about 2 inches deep in June or early July, after a crop of hay has been removed, the sod being then rolled and worked down thoroughly. As a result of this treatment a good crop of hay is secured the following season. Farther west, in Saskatchewan and in the drier portions of the Dakotas, breaking the meadow in the spring, about May, gives best results. This method is recommended by the experimental farm at Indian Head, Saskatchewan. Satisfactory results have been obtained in the more humid sections from shallow-breaking the sod in the spring and putting it in condition for a light seeding of grain, oats being frequently used. If thought necessary, 6 to 8 pounds of brome-grass seed is added. In this way a crop of grain is secured the same year, and a good crop of grass the next, so that the ground is not

allowed to lie idle. Returns are of course obtained from the land if the breaking is done in June or July after cutting a crop of hay. In the drier portions spring plowing is necessary, but since grain can not be sown on the sod no returns are obtained until the following year. Good results are sometimes secured from breaking the sod in the fall and sowing oats or some other small grain in the spring. When this is done the grass comes on for a full crop the next year. This method, however, is not commonly practiced.

Disking appears to give better results in the humid than in the drier sections, but in general it can hardly be said to give entire satisfaction. Better results are obtained on sandy or loose soil than on a heavy soil where a tough sod is formed. Farmers who have done very little toward improving their meadows are commonly of the opinion that disking is an effective means of renewing them, but actual experiments indicate that the value of this treatment is considerably overrated. Harrowing with a drag harrow in July after the hay is cut has proved beneficial in some instances.

The practice of applying barnyard manure to unproductive meadows has not been followed to any great extent, and under present conditions it is hardly practicable. The results obtained from such treatment have not been very definite, and in some cases they have been quite contradictory. That a liberal application of barnyard manure, even when no other treatment is given, will materially increase the yield of hay from a so-called "sod-bound" meadow has been proved by reliable and successful farmers. Best results have been obtained by applying an even top-dressing early in the spring before the grass begins to grow. Sheep manure has been found to be very beneficial.

Hardly sufficient evidence has been obtained to warrant definite statements regarding the value of various fertilizers. Prof. J. H. Shepperd, of the South Dakota Agricultural Experiment Station, in the season of 1905 obtained some results that were very favorable to the use of nitrate of soda. At the Highmore station, South Dakota, experiments conducted with the same fertilizers in 1906 gave rather indifferent results. The data available on the subject of renewing meadows by either barnyard manure or commercial fertilizers are so incomplete and the practice of renewal in this way is so unusual that it is not considered advisable to discuss the subject further at this time.

MIXTURES OF BROME-GRASS WITH OTHER GRASSES.

Some attention is being given to mixtures of brome-grass with other grasses, and very good results are being obtained. The practice

so far is very limited, and the proportions of the different grasses to use and the methods of handling have not been well worked out.

At present timothy seems to be the most common grass used in mixtures; alfalfa, red clover, slender wheat-grass, meadow fescue, and orchard grass are also used. Grasses and clovers are mixed with *Bromus inermis* to improve the quality and yield of forage and, for what is probably of more importance, to prolong the period of productiveness by keeping the brome-grass from becoming sod-bound. Results of experiments to determine this period have so far been rather indefinite. It is probable that the sod-bound condition can be delayed for a short while, but not for any great length of time. Alfalfa and clover are of value also, since they tend to maintain the productivity of the soil, and where these plants are mixed with brome-grass they can be pastured with little danger to stock from bloating.

Timothy has been grown with brome-grass at the Manitoba experiment farm with very good results, but it is the opinion there that it does not materially increase the life of a meadow and that the brome-grass eventually crowds it out. This mixture is quite commonly grown throughout Manitoba. Mixtures have been tried on the experiment farm at Indian Head, Saskatchewan, and one composed of 7 pounds of *Bromus inermis* and 7 pounds of slender wheat-grass (*Agropyron tenerum*) has given good results. A meadow of this mixture after having been down for six years without renewing still remained productive, yielding two tons of hay to the acre. In the Dakotas experiments are being conducted with alfalfa and brome-grass, and there is a probability of the combination coming into general use where alfalfa can be successfully grown. Mixtures with orchard grass and meadow fescue have given indications of being worthy of attention. In all permanent mixtures the quantity of brome-grass seed used should be smaller than the sum of the other constituents, as brome-grass has a tendency to crowd out the other grasses.

USES AND VALUE.

PASTURE.

Although grown as a general-purpose grass, *Bromus inermis* is much better adapted for use as pasture than for hay, on account of its tendency to form a turf. It furnishes a large quantity of palatable pasturage, and is especially valuable because it can be grazed early in the spring and late in the fall, and unless the season is unfavorable it furnishes a considerable amount of feed during the summer. Where it is now being grown there are no grasses that can equal it for pasture on sandy land, as it not only produces well on such soil, but forms a sod that withstands trampling and is not easily pulled up

by stock. This is an important feature, especially where sheep are grazed. Even after the grass has become sod-bound and produces only light yields of hay it can still be pastured profitably for two or three years. While it is impossible at the present time to secure definite data in regard to the carrying capacity of *Bromus inermis* pastures, it can be conservatively stated that both in favorable and unfavorable seasons they furnish more grazing in the western part of the Dakotas than the native grasses and more in the eastern part than Kentucky bluegrass.

HAY.

Brome-grass is not an ideal hay grass, although for two or three years after sowing it gives a satisfactory yield of a very good quality of hay. On rich land the yield is better than the average for standard grasses, and the quality is good. (See Pl. II, fig. 1.) It is generally agreed that the best stage at which to cut brome-grass for hay is just after it has passed full bloom and is in the condition known as the "purple." The practice is, however, quite elastic in this respect, as the grass makes hay of good quality when cut either before or after this stage. No definite feeding experiments have as yet been conducted to determine the value of brome-grass hay in comparison with other standard hays or fodder, but general experience indicates that it is almost, if not quite, equal to timothy for cattle (especially dairy cows), for horses not at work, and for sheep. When properly cured it is very palatable and is relished by all classes of stock, but on account of its laxative properties it can not be recommended as a feed for livery horses or horses at hard work.

Different writers in discussing brome-grass disagree in regard to its nutritive value as compared with a standard grass such as timothy. Chemical analyses disagree also, and it is difficult to compare these grasses, since the samples have been taken at different stages of maturity and also under otherwise different conditions. The average of analyses given in Bulletin 56 of the Iowa Agricultural Experiment Station shows water-free samples of *Bromus inermis* to contain 3.48 per cent of fat and 14.14 per cent of protein, and samples of timothy under the same conditions to contain 4.83 per cent of fat and 12.27 per cent of protein. These analyses indicate that the grasses are near enough alike to be of equal feeding value. The verdict of the feeder, however, is in most cases to be taken in preference to that of the chemist, and it is doubtful whether brome-grass will ever be considered quite equal to timothy as feed for stock.

Brome-grass is usually ready to cut for hay from the last of June until the 20th of July, depending on the locality. When conditions are favorable, it is possible to secure two cuttings, the first about

the last of June or early in July, and the second in September. The securing of two crops depends almost entirely on the amount of moisture and very little on the latitude, since in eastern Manitoba two are frequently obtained. Except under irrigation, only one cutting can usually be secured in the western part of the Dakotas or at the same longitude in Canada. The first cutting yields more and is of much the better quality. The second cutting, although nearly as tall as the first when cut, consists mostly of leaves and makes very light hay.

The hay does not cure as easily as timothy and darkens rapidly if allowed to get wet. Although this makes it unsalable, its feeding value is not seriously impaired. Even when properly cured, however, the hay is of darker color than timothy.

Stacking is done with the ordinary hay-making machinery, and when put up with reasonable care the stacks shed water well and will keep for two years in excellent condition, with but a small quantity of damaged hay on the outside. (See Pl. II, fig. 2.)

As previously stated, in the third season of growth the maximum yield is usually secured. After two crops are obtained the yield rapidly diminishes. The average yield for the time the meadow is profitable, which is three or four years, may be conservatively estimated at $1\frac{1}{2}$ tons per acre. This is the estimated average yield for the entire region. On good soil and under favorable conditions yields as high as 3 to 4 tons are not uncommon, especially when two cuttings a year can be secured.

Brome-grass hay is very little known on the city market and the demand for it is entirely local. It commands a good price in sections where it is grown, and ordinarily sells for \$2 to \$3 a ton more than native wild hay and for about the same price as timothy.

SEED.

There is a considerable quantity of brome-grass seed produced throughout the entire region under discussion, although it is grown to the largest extent in the eastern part of the Dakotas, in Manitoba, and in eastern Saskatchewan. The growing of seed in large quantities seems to have been more of an industry a few years ago than it is at the present time. It should not be inferred from this that the total quantity produced is not as great as heretofore, but that farmers are growing it less for wholesale market and more for local use, making its production more generally distributed. Whether there is actually less produced it is difficult to state; there is certainly less imported than formerly. There are many farmers who have in the past grown 100 acres, and even much more, for seed who at the present time are raising little more than enough for their own use.

FIG. 1.—A FIELD OF BROME-GRASS IN NORTH DAKOTA.

FIG. 2.—STACKING BROME-GRASS IN NORTH DAKOTA.

HARVESTING THE SEED.

The seed is mature and ready to cut from July 10 to August 1, and the stage of maturity is commonly termed the "brown" to distinguish it from the "purple," or the stage when the grass is cut for hay. Harvesting the seed is a comparatively easy matter and differs very little from the harvesting of ordinary cereals. The binder and the header are both used, but the former is the most generally employed. When the binder is used the grass is usually cut as high as possible and the bundles put in long shocks to facilitate curing. They are allowed to remain in shocks until thrashed. When the grass can be cut sufficiently high a crop of hay is obtained from the stubble as soon as possible after the seed is removed. This hay is of very fair quality, as it contains a large quantity of green leaves.

While the binder is most commonly used in harvesting, heading appears to be the best method. When it is used, almost all of the grass is left for hay, which makes quite an additional yield from the meadow. After heading, the seed is put up in well-built shocks for curing, and is usually left there from ten days to two weeks or even longer. If conditions are exceptionally favorable, it is possible to thrash directly from the header box. This is not frequently done, since the thrashing machines are not usually ready at that time of the year. The stubble is cut for hay as soon as possible after heading, and yields on an average about a ton to the acre.

Occasionally the grass is cut with a mowing machine and put in ordinary stacks for thrashing. This method is not considered desirable on account of the waste and difficulty in handling.

THRASHING.

Brome-grass is thrashed with the ordinary machine having special riddles and with the wind shut off from the fan to prevent the seed from blowing over. Difficulty is often met with in getting the cleaned seed to elevate properly in the machine, and in many cases the elevator is removed and the seed delivered from the spout at the bottom of the separator. The seed is likely to contain a great amount of chaff and broken pieces of straw after thrashing. This trash is sometimes quite difficult to separate from the seed, and it is necessary to run it through a fanning mill. By withdrawing the bundles from the cylinder after the heads have been thrashed, the seed is kept comparatively free from straw and chaff. This method involves much work and is hardly practicable where a large quantity is to be thrashed.

YIELD OF SEED.

The yield of seed is so variable, depending on the climate, soil, lay of the meadow, and other factors, that it is difficult to estimate the average quantity produced to the acre. From 250 to 350 pounds is, however, a conservative estimate. Records of the Saskatchewan experimental farm show the yield of brome-grass seed there to range from 250 to 600 pounds. Experiments conducted at the Manitoba experimental farm indicate that the harvesting of a mature crop of seed materially lessens the yield of either hay or seed the following year.

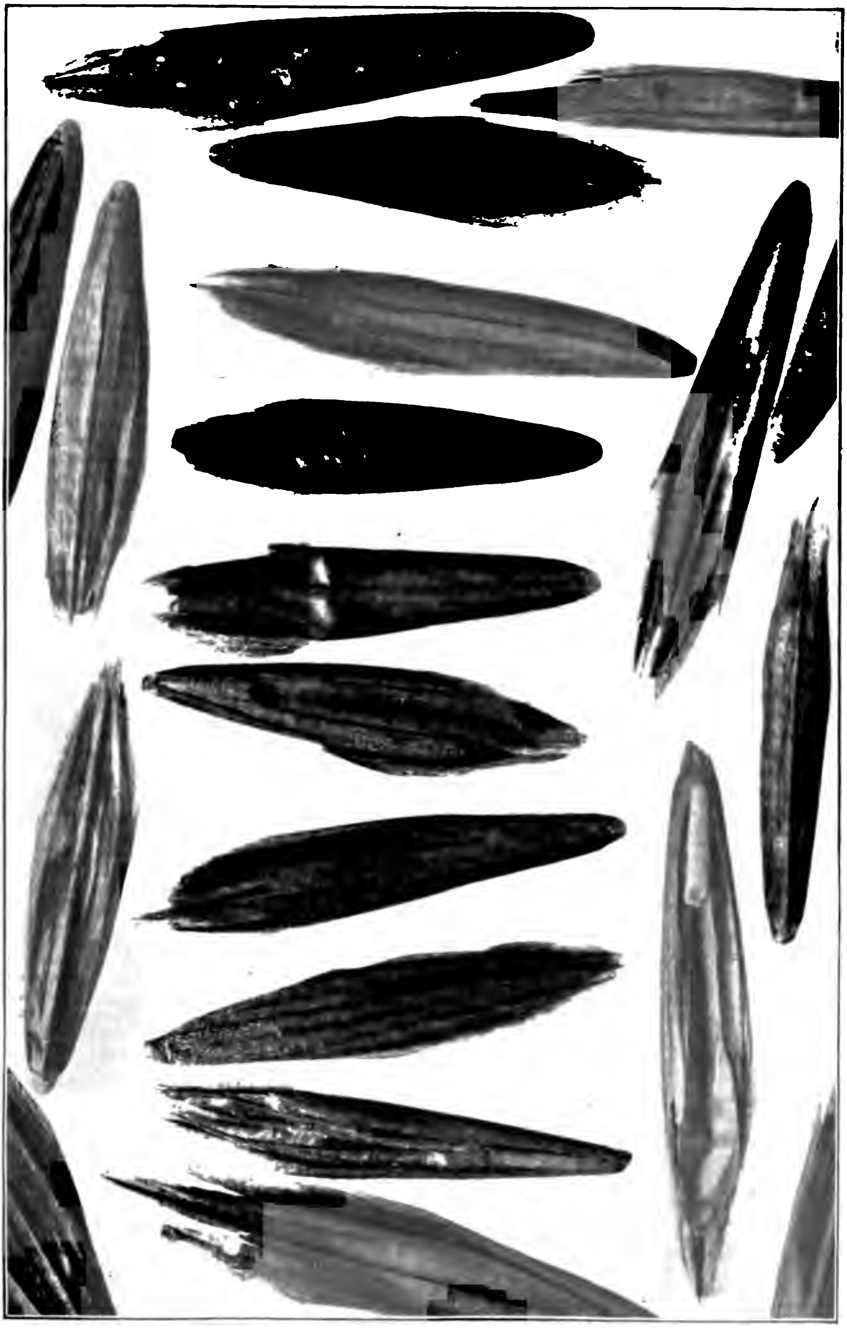
On account of the close sod formed by the grass after the first year there are very few weeds present in the fields, and consequently the seed when harvested is practically free from impurities and in very few cases are there seeds of any other grasses in it. There is occasionally a very small amount of seed of the grain used as a nurse crop and a trace of cheat (*Bromus secalinus*) and slender wheat-grass (*Agropyron tenerum*). The seeds of *Bromus inermis* are very similar to those of the above species, the seeds of chess, especially, often being mistaken for brome-grass seeds. (See Pl. III.)

STRAW.

When cut with a binder, the straw after thrashing is generally stacked and used for feed. The quality varies largely with the height at which the grass is cut, the length of time it stands in the shock, and the care with which it is stacked after thrashing. If all these conditions are favorable, brome-grass straw is about equal to oat straw. At any rate, it makes very fair feed for wintering cattle, horses, and sheep.

USE IN ROTATION.

One of the objections which farmers have to brome-grass is that it is comparatively short lived and will not remain productive for hay in a meadow more than three or four years. This objection is not serious from the standpoint of crop rotation, but, on the other hand, is slightly advantageous, since there is a general tendency to grow one crop on a field for too long a period. *Bromus inermis*, however, is not looked upon by farmers as a valuable constituent in a crop rotation. This is due to the fact that it is considered difficult to eradicate, and when ordinary methods are employed it takes about two years to get it out of the field. Farmers desire something that can be disposed of easily in one year or with one plowing, and consequently are favoring slender wheat-grass (*Agropyron tenerum*), which is now coming into popularity on this account.



SEEDS OF BROME-GRASS (BROMUS INERMIS).

(Magnified six diameters.)

PREPARATION OF BROME-GRASS MEADOWS FOR OTHER CROPS.

The breaking up of a brome-grass meadow and the preparation for other crops is a very important matter. It has been found at the Manitoba experimental farm that plowing the sod after a crop of hay has been cut and the aftermath has made a growth of 3 or 4 inches gives very satisfactory results. The plowing may be done the latter part of June or the first of July and the sod back-set either in the fall or early in the spring and put in condition for wheat or other grains by disking and harrowing. If the aftermath is allowed to grow to the extent above indicated, it assists very materially in rotting the sod and also supplies additional humus. When the breaking is done immediately after a crop of hay or seed is harvested, the sod does not rot well, especially if the season is dry, and consequently the ground is in poor condition for a crop the following spring.

A method which has been found to be practicable, at least in the eastern portion of the Dakotas, is to break early in the spring after the grass gets a good start, then disk and roll thoroughly, and in June sow to flax at the rate of about half a bushel to the acre. In this case, unless the flax makes a good stand there will be some danger of the brome-grass making a sufficient growth to become troublesome. Where flax is a successful crop, it can follow brome-grass to good advantage. No matter what method is practiced, the grass is likely to give trouble the first season on account of its persistence, but if properly handled will not be a serious menace. It is necessary in the drier sections to break the sod when the moisture conditions are favorable, whether in fall or spring, as it is very difficult to break and does not rot readily. On account of the latter fact the sod requires considerable working in the sections of low rainfall.

MISCELLANEOUS USES.

The aggressive nature of brome-grass fits it for certain uses and situations for which the common standard grasses are not adapted. It is very valuable for putting heavy new land in condition for other crops. The rich heavy soil of river bottoms, which are frequently covered with a dense growth of weeds and brush, may be put in good condition by seeding heavily after clearing and plowing. At the end of two years the grass comes on to the exclusion of the weeds and makes an excellent hay meadow.

There are certain classes of soil that after having been plowed for five or six years become very loose and blow badly and are in poor mechanical condition for ordinary crops. When *Bromus inermis* is grown on such land for a few years it adds a sufficient amount of

humus to the soil to return it to good condition. The grass is also very valuable for preventing sandy land from blowing.

Brome-grass is an excellent crop for combating such weeds as fox-tail, or squirrel-tail (*Hordeum jubatum*), and on moist land, where the latter flourishes, the former excludes it very effectually.

THE AGRICULTURAL EXTENSION OF BROME-GRASS.

Little has been done in the matter of extending the growing of *Bromus inermis* farther east at the same latitude as its present region. Experiments that have been conducted with it in various sections east of Minnesota and north of Kansas indicate that it is worthy of extension. It will doubtless prove valuable on sandy soil in Wisconsin, New York, and New England, but will probably be of use mostly as a pasture grass and in mixtures with other grasses. In parts of Ohio, West Virginia, Pennsylvania, Maryland, and Virginia where tested it has shown considerable promise. South of these States it is of questionable value.

Brome-grass should be given a thorough test as a sand-binding grass along the Lakes and near the seacoast, as its extensive root system and its ability to thrive on sandy land make it well adapted to such situations. Some very striking results have been obtained with it on sandy soil on the upper peninsula of Michigan. Under similar conditions in Wisconsin its value, especially as a pasture grass, has been quite thoroughly demonstrated. In these States it is said to be at least ten days earlier for pasture in the spring than the ordinary standard grasses.

While the thorough testing of brome-grass by farmers in the States mentioned is strongly urged, its use on a large scale is not considered advisable until its value as compared with the standard grasses commonly grown in these States has been more definitely demonstrated.

SUMMARY.

Brome-grass (*Bromus inermis*) is at present of most importance in the Dakotas and sections adjoining these States, but is grown to some extent throughout the general region from Kansas north to the Canadian boundary and west to the Pacific coast. Its importance in the timothy region is as yet very limited.

It is the common practice to sow the seed in the spring about the 1st of April, or as soon as the weather is favorable. One bushel of 14 pounds is considered a sufficient quantity to produce a satisfactory stand, and good results are obtained with 10 to 12 pounds. Heavier seeding is recommended in sections where the grass is being tested or where it is intended for pasture alone.

Under ordinary conditions a brome-grass meadow remains productive from three to four years, after which it becomes what is commonly called "sod-bound." The meadow can be successfully renewed by breaking the sod lightly, the time of breaking depending largely on the annual rainfall.

Mixtures of brome-grass with other grasses and clovers have proved very satisfactory as far as they have been tried. Timothy, slender wheat-grass, orchard grass, meadow fescue, alfalfa, and red clover are used in these mixtures.

Brome-grass is a valuable general-purpose grass, but is much better adapted for use as pasture than for hay, as it furnishes a large amount of grazing, especially in the spring and late in the autumn. The yield of hay which it produces is good and the quality very satisfactory.

The seed habit of brome-grass is good, which makes it comparatively easy to harvest and thrash. Average yields of about 300 pounds to the acre are obtained.

In crop rotation brome-grass has not as yet become well established, and by some it is looked upon rather unfavorably on account of being somewhat difficult to get out of the land. Good crops, however, are raised after it, and it adds a considerable amount of humus to the soil.

It is often difficult to prepare brome-grass sod for succeeding crops, as it does not rot readily, and for this reason it is necessary to backset after breaking. The time of breaking depends on the rainfall.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 112.

B. T. GALLOWAY, *Chief of Bureau.*

THE USE OF SUPRARENAL GLANDS IN THE PHYSIOLOGICAL TESTING OF DRUG PLANTS.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 24, 1907.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 112 of the series of this Bureau, the accompanying technical manuscript entitled "The Use of Suprarenal Glands in the Physiological Testing of Drug Plants." This paper was prepared by Dr. Albert C. Crawford, Pharmacologist in Drug-Plant Investigations, as one of a series of publications on the subject of drug testing, and has been submitted by Dr. Rodney H. True, Physiologist in Charge, with a view to its publication.

This paper is preliminary to a consideration of the subject of the testing of ergot, one of the most valuable and variable of vegetable drugs. It has been proposed by recent investigators that the most acceptable means of measuring the activity of ergot is to standardize it against a known preparation of the active principle of the suprarenal glands. In order, therefore, to enable us to carry out the ergot test, the presentation of a means of standardizing the active principle of suprarenal glands is a preliminary step.

Among the great advance steps taken by medicine in later years, the attempt to bring medicinal agents to a known and, when possible, uniform standard of action is one of the most important. Many drugs are now standardized by chemical methods and can be administered by the physician in full confidence that his remedy is capable of exerting the desired degree of action. In the case of others in which the active principles are not as yet known or in which the principle will not admit of isolation, testing by physiological means has come to be recognized as a prime necessity. Since this phase of drug investigations is still young, a considerable diversity in methods exists. It is hoped that this paper, which treats of methods of testing the active principle of suprarenal glands, may contribute toward greater uniformity in this important matter and make more generally available than is now the case the essentials of an important means whereby physiology may serve medicine.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE USE OF SUPRARENAL GLANDS IN THE PHYSIOLOGICAL TESTING OF DRUG PLANTS.

INTRODUCTION.

It has long been recognized that many of the important pharmacopœal preparations can not be accurately standardized by any known chemical processes, so that for this purpose physiological methods have been employed.[a]

There have been some inquiries as to where information concerning this subject could be obtained, and as most of the data occur in sources which are not usually accessible it was deemed wise to abstract this literature and present the methods in some detail. It must be remembered that as our knowledge increases these tests are sure to suffer change, a fate which has been the lot of chemical assay processes. A few years ago gravimetric assay methods were used almost entirely, but now only when titration methods are unavailable. These methods have become an essential to all analytical pharmaceutical laboratories, and thousands of dollars are spent every year in this country for carrying out these tests.

While often mechanically simple in their execution they require considerable experience to interpret them properly, and for this reason some of the large drug firms err in employing inexperienced persons to perform them.

These tests can be used not only with preparations in which the active principle is little known, but also to control chemical processes where the active principle is well recognized. Thus the writer has controlled the assay for atropin by noting the minimum quantity necessary to cause dilatation of the pupil and standardizing this with a known solution of atropin.

[a] Standardization of pharmaceutical preparations. Brit. Med. Jour., vol. 2, p. 583, 1906.

No one would now think of using any of the aconitins in medicine without first determining their toxicity, whatever the result of the chemical assay.

Kobert has called attention to this increased importance of the pharmacologist and has claimed that these tests should be an essential for all medico-legal cases, and he has shown that the physiological test may respond where the chemical one is not sufficiently delicate.[a]

Certain simple physiological tests, such as the dilatation of the pupil with atropin, the production of a tingling sensation in the tongue by aconite, and the correct tasting of preparations, have been recognized by the Pharmacopœia, and the testing of diphtheria antitoxin has at last obtained recognition.[b]

It must be remembered that animals respond differently according to various conditions. Thus Dixon[c] has cited the influence of cerebral development in animals as influencing the response to cocain, as follows:

Animal.	Grams of brain per kilo of animal.	Dose of cocain per kilo of animal necessary to produce convulsions.
Rabbit	4	0.18
Guinea pig	7	.07
Pigeon	8	.06
Dog	9	.02
Ape	18	.012

Various other illustrations could be given, so that the animals in most cases should correspond as nearly as possible in species, sex, age, and weight.

SUPRARENAL GLANDS.

SEPARATION OF THE ACTIVE PRINCIPLE.

Attention was recently called to the marked blood-pressure-raising properties of the suprarenal glands in the work of Oliver and Schaefer,[d]

[a] Kobert, R. Ueber d. Bedeutung d. biologisch. Giftnachweis f. d. gerichtl. Med. Ber. d. Deutsch. Pharm. Gesells., vol. 13, p. 325, 1903.

Scholtz, K. Wertbestimmung d. Jequiritols u. d. Jequiritol-Heilserums durch Tierexperimente. Arch. f. Augenheilkunde, vol. 55, p. 209, 1906.

[b] Otto, R. Die staatliche Prüfung d. Heilsera. Arbeit. a. d. Königl. Institut f. Exper. Therapie z. Frankfurt, 1906.

[c] Dixon, W. E. Bio-chemical standardization of drugs. Pharm. Jour., vol. 75, p. 156, 1905.

[d] Oliver, G., and Schaefer, E. A. Physiological effects of extracts of suprarenal capsules. Jour. Physiol., vol. 18, p. 230, 1895.

On the physiological action of extract of the suprarenal capsules. Proc. Physiol. Soc., p. i, Jour. Physiol., vol. 16, 1894; Proc. Physiol. Soc., p. ix, Jour. Physiol., vol. 17, 1894–95.

and later by Cybulski, Szymonowicz, Boruttau, and others.[a] Vulpian [b] had in 1856 noted the presence in them of certain principles giving peculiar color reactions, and from this time these color reactions were believed to be due to the presence of pyrocatechin or a derivative of it.[c]

The chemical work—at least that which has been done in this country—has been carried out mainly from the influence of Professor Abel's laboratory. Abel himself isolated a body to which he gave the name epinephrin, and calculated the empirical formula to be $C_{17}H_{15}NO_4$, but he was compelled to change this to $C_{10}H_{11}NO_3$ by the withdrawal of one benzoyl group, and later to $C_{10}H_{13}NO_3\frac{1}{2}H_2O$.[d]

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[a] Szymonowicz, L. Die Function d. Nebenniere. Arch. f. Gesam. Physiol., vol. 64, p. 97, 1896.

Boruttau, H. Erfahrung. über d. Nebennieren. Arch. f. Gesam. Physiol., vol. 78, p. 97, 1899.

[b] Vulpian, A. Note sur quelques reactions propres à la substance des capsules surrénales. Comp. Rend. Acad. des Sci., vol. 43, p. 663, 1856.

Cloez, S., and Vulpian, A. Note sur l'existence des acides hippurique et choléique dans les capsules surrénales des animaux herbivores. Comp. Rend. Acad. des Sci., vol. 45, p. 340, 1857.

[c] Krukenberg, C. F. W. Die farbigen Derivate der Nebennierenchromogene. Arch. f. Path. Anat., vol. 101, p. 542, 1885.

Brunner, H. Zur Chemie d. Lecithine u. d. Brenzcatechins, Bestandtheile der Nebennieren. Schweiz. Woch. f. Chem. u. Pharm., vol. 30, p. 121, 1892.

Mühlmann, M. Zur Physiologie der Nebenniere. Deutsch. Med. Woch., vol. 22, p. 409, 1896.

Fraenkel, S. Beitr. z. Physiol. u. physiol. Chemie d. Nebenniere. Wien. Med. Blätter, vol. 19, pp. 211, 228, 246, 1896.

[d] Abel, J. J., and Crawford, A. C. On the blood-pressure-raising constituent of the suprarenal capsule. Johns Hopkins Hospital Bul., vol. 8, p. 151, 1897.

Abel, J. J. Ueber den blutdruckerregenden Bestandtheil d. Nebenniere, das Epinephrin. Zeits. f. Physiol. Chemie, vol. 28, p. 318, 1899.

Further observations on epinephrin. Johns Hopkins Hospital Bul., vol. 12, p. 80, 1901.

On epinephrin and its compounds. Amer. Jour. Pharm., vol. 75, p. 301, 1903.

Weitere Mittheil. ü. d. Epinephrin. Ber. d. Deutsch. Chem. Gesells., vol. 36, p. 1839, 1903.

The function of the suprarenal glands. Contrib. to Med. Research, dedicated to V. C. Vaughan, 1903, p. 138.

On the phenylcarbamic esters of epinephrin. Proc. Amer. Physiol. Soc., 1899, p. xvii, Amer. Jour. Physiol., vol. 3, 1900.

On a simple method of preparing epinephrin and its compounds. Johns Hopkins Hospital Bul., vol. 13, p. 29, 1902.

Abel, J. J., and Taveau, R. de M. On the decomposition products of epinephrin hydrate. Jour. Biol. Chem., vol. 1, p. 1, 1905.

NOTE.—Full literature on the suprarenals may be found in Möller, S., Kritisch-exper. Beitr. z. Wirkung d. Nebennierenextraktes, Dissert., Berlin, 1906.

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Von Fürth[a] obtained a principle which he named suprarenin and gave the formula $C_5H_9NO_2$ or $C_5H_7NO_2$, but later changed this to $C_9H_{13}NO_3$.

Takamine[b] simplified the method of isolation and made it commercially available, giving his preparation the name adrenalin, with the formula $C_{10}H_{15}NO_3$.

Simultaneous with Takamine's paper, Aldrich, Abel's former associate, published his results.[c] His body was evidently much purer than Takamine's, as he purified before precipitating, but his method was not commercially available on account of the necessary purification from the lead. Aldrich adopted Takamine's name adrenalin, although his formula $C_9H_{13}NO_3$ differed by CH_2 from that of Takamine. These two preparations are often confused. Aldrich pointed out that if the benzoyl group was removed from Abel's original formula, the resultant formula was close to his. All three investigators—Abel, Takamine, and Aldrich—were dealing with the same body, but in varying degrees of purity.

Abel has compared the analytical data furnished by Aldrich and Takamine, and declares that the analyses do not bear out the empirical formulæ deduced.[d] The formula of Aldrich has been corroborated by Bertrand in France,[e] and adopted by Pauly, von Fürth, Stolz, Abderhalden, and Bergell, in Germany.[f] The two latter investigators used Abel's purification method, but came to different conclu-

[a] Von Fürth, O. Zur Kenntniss d. brenzkatechinähnlich. Substanz in d. Nebennieren. Zeits. f. Physiol. Chemie, vol. 24, p. 142, 1898; vol. 26, p. 15, 1898–99; vol. 29, p. 105, 1900.

Zur Kenntniss des Suprarenins. Beitr. z. Chem. Phys. u. Path., vol. 1, p. 243, 1902.

Zur Kenntniss des Suprarenins (Adrenalins). Sitz. d. Kaiserl. Akad. d. Wissen. Wien, Math.-natur. Kl., vol. 112, pt. 3, 1903.

Zur Kenntniss des Suprarenins (Adrenalins). Monats. f. Chem., vol. 24, pp. 261–290, 1903.

[b] Takamine, J. Adrenalin, the active principle of the suprarenal glands. Amer. Jour. Pharm., vol. 73, p. 523, 1901.

The blood-pressure-raising principle of the suprarenal glands. Therap. Gaz., vol. 25, p. 221, 1901.

[c] Aldrich, T. B. Preliminary report on the active principle of the suprarenal gland. Amer. Jour. Physiol., vol. 5, p. 457, 1901.

Adrenalin, the active principle of the suprarenal glands. Jour. Amer. Chem. Soc., vol. 27, p. 1074, 1905.

[d] Abel, J. J. On epinephrin and its compounds. Amer. Jour. Pharm., vol. 75, p. 309, 1903.

[e] Bertrand, G. Sur la composition chimique et la formule de l'adrénaline. Comp. Rend. Acad. d. Sci., vol. 139, p. 502, 1904.

[f] Pauly, H. Zur Kenntniss des Adrenalins. Ber. d. Deutsch. Chem. Gesells., vol. 36, pt. 3, p. 2944, 1903; vol. 37, pt. 2, p. 1388, 1904.

Abderhalden, C., and Bergell, P. Zur Kenntniss d. Epinephrins. Ber. d. Deutsch. Chem. Gesells., vol. 37, pt. 2, p. 2022, 1904.

Ueber d. Epinephrin. Münch. Med. Woch., vol. 51, p. 1003, 1904.

sions from Abel. It was also adopted by Jowett and by Barger and Ewins in England.[a] These latter authors are especially emphatic in support of Aldrich's formula. These differences in results have not yet been finally adjusted.[b] The difficulty may be due to the fact that there is in adrenalin a series of chemically similar bodies,[c] as it is well known that blood-pressure-raising properties and the chemical reactions shown by adrenalin are given by other pyrocatechin derivatives.[d]

The active principle resides largely in the medullary portion of the suprarenal glands, although the cortex also contains some.[e] Accessory suprarenal glands which are found in various portions of the abdominal cavity also contain principles having blood-pressure-raising properties. Blood-pressure-raising principles are also claimed to be present in other organs, pituitary bodies, etc.[f]

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[a] Jowett, H. A. D. The constitution of epinephrin. Jour. Chem. Soc. Trans., vol. 85, p. 192, 1904.

Barger, G., and Ewins, A. J. Note on the molecular weight of epinephrin. Chem. News, vol. 93, p. 90, 1906.

NOTE.—For a review of the relation of the early chemical workers, see Maben, T., Adrenalin: the active principle of the suprarenal gland, in Pharm. Jour., 1907, p. 388. A reply to Maben is found in Martin, W., Epinephrin or adrenalin, in Pharm. Jour., 1907, p. 447.

[b] Aldrich, T. B. Is adrenalin the active principle of the suprarenal gland? Amer. Jour. Physiol., vol. 7, p. 359, 1902.

[c] Halle, W. L. Ueber d. Bildung d. Adrenalins im Organismus. Beitr. z. Chem. Physiol. u. Pathol., vol. 8, p. 277, 1906.

Elliott, T. Action of adrenalin. Jour. Physiol., vol. 32, p. 462, 1905. Elliott writes as follows: "By bubbling oxygen through adrenalin solution (Parke-Davis's 0.1% HCl solution, diluted to 1:2,000 and exactly neutralised with Na_2CO_3) I obtained a brown liquid which contained no adrenalin, but was fairly potent to cause vaso-constriction. In this respect it had one-twentieth of the power of adrenalin. But even 4 c. c. of the solution, which correspond to an original content of 2 mgm. adrenalin, and in respect of ability to raise blood pressure to 0.1 mgm. of adrenalin, caused no movements of iris or nictitating membrane. In the same test cat 0.03 mgm. adrenalin gave maximal rise of blood pressure and typical eye movements. Four c. c. of the oxydised solution were then injected beneath the skin of a rabbit, and caused neither glycosuria nor prostration."

Moore B., and Purington, C. On the chromogen of the suprarenal medulla. Proc. Amer. Physiol. Soc., 1899, p. xvi; Amer. Jour. Physiol., vol. 3, 1900.

[d] Dakin, H. D. On the physiological activity of substances indirectly related to adrenalin. Proc. Royal Soc. London, ser. B, vol. 76, p. 498, 1905.

[e] Salvioli, I., and Pezzolini, P. Sur le différent mode d'agir des extraits médullaire et cortical des capsules surrénales. Arch. Ital. de Biol. vol. 37, p. 380, 1902.

[f] Schmid, J. Ueber d. blutdrucksteigernde Substanz d. Niere. Med. Klinik, 1906, p. 976.

Livon, C. Sécrétions internes: Glandes hypertensives. Comp. Rend. Hebd. Soc. de Biol., vol. 50, p. 98, 1898.

Brown, O. H., and Joseph, D. R. Effects of intravenous injections of extracts of the bone marrow. Amer. Jour. Physiol., vol. 16, p. 110, 1906.

COLOR TESTS.

Adrenalin is described as a microcrystalline powder which possesses basic properties and acts as a reducing agent. Strictly speaking, this body can not be classed with the alkaloids.

Freshly prepared solutions are colorless, but become rose colored under the influence of light and air, especially in dilute solutions. After long standing these solutions finally become brown and lose their activity. This oxidation especially occurs in an alkaline medium, so that commercial solutions are usually made acid.[a]

The active principle when in solution gives a green color on the addition of ferric chlorid. This green passes into a purple and finally into a carmine on the addition of ammonia. A dilute solution of iodin turns adrenalin solution to a rose color.

This production of a green color with ferric chlorid has been utilized by Battelli[b] as a method of estimating the amount of active principle present. The formation of this color is, however, influenced by acidity and appears badly in very acid solutions,[c] but the main difficulty with this method is that the delicate green is hard to recognize in great dilution.

Cameron[d] states that this is a rough method for assaying solutions of over 1–40,000 and that it fails for brown or solutions more dilute than 1–40,000.

Von Fürth[e] has also proposed a color test with iron chlorid, sodium carbonate, and potassium sodium-tartrate, but this does not offer any advantages and is subject to the same criticism as other color reactions.

Abelous, Soulié, and Toujan[f] have proposed using the iodin reaction for the same purpose, judging not by the amount of iodin used but by the shade of rose color produced. This is ascertained by con-

[a] Livon, C. Action des vieilles solutions d'adrénaline. Comp. Rend. Hebd. Soc. de Biol., vol. 1, p. 125, 1904.

Battelli, F. Transformation de l'adrénaline "in vitro." Comp. Rend. Hebd. Soc. de Biol., vol. 54, p. 1435, 1902.

[b] Battelli, F. Dosage colorimétrique de la substance active des capsules surrénales. Comp. Rend. Hebd. Soc. de Biol., vol. 54, p. 571, 1902.

[c] Boulud, R., and Fayol. Sur le dosage colorimétrique de l'adrénaline. Comp. Rend. Hebd. Soc. de Biol., vol. 55, p. 358, 1903.

[d] Cameron, I. D. On the methods of standardising suprarenal preparations. Proc. Roy. Soc. Edinburgh, vol. 26, p. 157, 1906.

[e] Von Fürth, O. Zur Kenntniss der brenzcatechinähnlich. Substanz d. Nebennieren. Zeits. f. Physiol. Chem., vol. 29, p. 115, 1900.

Zur Kenntniss des Suprarenins. Beitr. z. Chem. Physiol. u. Path., vol. 1, p. 244, 1902.

[f] Abelous, J. E., Soulié, A., and Toujan, G. Dosage colorimétrique par l'iode de l'adrénaline. Comp. Rend. Hebd. Soc. de Biol., vol. 1, p. 301, 1905.

Sur un procédé de contrôle des dosages chimique et physiologique de l'adrénaline. Comp. Rend. Hebd. Soc. de Biol., vol. 60, p. 174, 1906.

trasting it with a standard solution of adrenalin freshly prepared which has also been treated with iodin. By this method they claim that the suprarenal glands (sheep) contain 1.47 mg. in every gram, while they state that Batelli by his method found 1.45 mg.[a]

Details of this method can be found in English in C. E. Vandekleed's "Method for the preparation of the active principle of the suprarenal gland" (Pharmaceutical Era, 1906, vol. 36, p. 478).

PRINCIPAL PHYSIOLOGICAL TESTS.

Toujan,[b] one of the originators of the iodin color test, states that the physiological response is more delicate than the chemical, although he objects to the former as being too inconstant for vigorous results. One of the difficulties with color reactions as a quantitative test is the fact that nothing is known as to whether in decomposition of the active principle the change in color reactions runs parallel with the loss in blood-pressure-raising properties; in fact, the evidence rather makes this doubtful. Battelli claims that certain suprarenal glands on removal from the body lose their reaction to iron chlorid, but retain their blood-pressure-raising properties.[c] When injected into the vein of an animal an extract of these glands or a solution of the active principle will cause a marked rise in the general blood pressure associated with a temporary slowing of the heart, owing to an action on the vagus centers, but if the vagi are cut or atropin is given before the injection of the suprarenal preparation, instead of the cardiac slowing there will be a marked acceleration of the heart beats and the maximum blood pressure effect will be obtained.[d] This rise in blood pressure is mainly due to a local action on the small blood vessels, or rather on the sympathetic nerve terminals in their walls.[e] In fact, Elliott considers that a "positive reaction with adrenalin is a trustworthy proof of the existence and nature of sympathetic nerves in any organ."

[a] Compare Battelli, F., and Ornstein, S. La suppléance des capsules surrénales au point de vue de leur richesse en adrenaline. Comp. Rend. Hebd. Soc. de Biol., vol. 61, p. 677, 1906.

[b] Toujan, G. Recherches expér. sur l'adrénaline. Thèse, Toulouse, 1905, p. 40.

[c] Ornstein, S. Suppléance des capsules surrénales. Thèse, Genève, 1906, p. 12.

[d] Elliott, T. R. Action of adrenalin. Jour. Physiol., vol. 32, p. 447, 1905.

Mathieu, X. Action de l'adrénaline sur le coeur. Jour. de Physiol. et de Path. Gen., vol. 6, p. 435, 1904.

Kahn, R. H. Beob. über d. Wirkung d. Nebennierenextractes. Arch. f. Anat. u. Physiol., Physiol. Abtheil., 1903, p. 522.

Plumier, L. Action de l'adrénaline sur le circulation cardiopulmonaire. Jour. de Physiol. et de Path. Gen., vol. 6, p. 655, 1904.

[e] Brodie, T. G., and Dixon, W. E. Contributions to the physiology of the lungs. Jour. Physiol., vol. 30, p. 476, 1904.

See also von Frey. Beitr. z. Kenntniss d. Adrenalinwirkung. Sitzb. d. Phys. Med. Gesells. z. Würzburg, 1905, p. 43:50.

Besides this action on the sympathetic nerve terminals there is some action on the heart itself.[a]

ACTION ON THE EYE.

The action on the small blood vessels is well shown by dropping a dilute solution into the conjunctival sac of an animal, when the conjunctiva becomes pale and bloodless and the pupil dilates.[b] This action on the conjunctiva occurs even after the use of solutions as dilute as 1–120,000. The action on the pupil of the excised frog eye has been advocated by Ehrmann[c] as a method for determining the amount of active principle present in unknown solutions, but the objection to this method is the difficulty in exactly measuring the size of the pupil and the uncertainty as to absorption through the eye membranes. In Ehrmann's hands, 0.000025 mg. could be thus determined with certainty, although 0.0000001 gram produced a distinct dilatation, while 0.00000005 gram was inactive. Cameron's results with this method were unsatisfactory.

ACTION ON ANIMALS.

A second method of showing this vaso-constrictor action is by perfusion of the blood vessels in frogs. Läwen[d] has obtained a response showing a decided constriction of the vessels with 0.2 per million adrenalin, but the method is tedious and frogs vary much in their response. Cameron obtained a feeble reaction with 0.1 per million. Details of this method may be found in English in Cameron's paper. Meyer[e] placed sections of the beef subclavian arteries in Ringer's solution with the addition of adrenalin. He found that most of them responded with under 1-100,000,000, but not all. With increasing amounts of adrenalin the contraction was greater—usually 1-50,000

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[a] Gottlieb, R. Ueber d. Wirkung d. Nebennierenextracte auf Herz u. Blutdruck. Arch. f. Exp. Path., vol. 38, p. 99, 1897.

[b] Meltzer, S. J., and Auer, K. M. Ueber d. Einfluss d. Nebennierenextraktes auf d. Pupille d. Frosches. Cent. f. Physiol., vol. 18, p. 317, 1904.

Kahn, R. H. Ueber d. Beeinflussung d. Augendruckes durch Extrakte chromaffinen Gewebes (Adrenalin). Zent. f. Physiol., vol. 20, p. 33, 1906.

Lewandowsky, M. Ueber d. Wirk. d. Nebennierenextractes auf d. glat. Muskeln, im besond. des Auges. Arch. f. Anat. u. Phys., Physiol. Abtheil., 1899, p. 360.

[c] Ehrmann, R. Ueber eine physiol. Werthbestimmung des Adrenalins. Arch. f. Exper. Path. u. Pharmakol., vol. 53, p. 97, 1905.

Zur Physiol. u. experiment. Path. der Adrenalinsekretion. Arch. f. Exp. Path. u. Pharmakol., vol. 55, p. 39, 1906.

Ueber die Wirkung des Adrenalins auf die Hautdrüsensekretion des Frosches. Arch. f. Exp. Path. u. Pharmakol., vol. 53, p. 137, 1905.

[d] Läwen, A. Quantitative Untersuchungen über d. Gefässwirkung von Suprarenin. Arch. f. Exp. Path. u. Pharmakol., vol. 51, p. 422, 1904.

[e] Meyer, O. B. Ueber einige Eigenschaft. d. Gefässmuskulatur. Zeits. f. Biol., vol. 48, p. 365, 1906.

gave the maximum, although some gave the maximum contraction with 1-100,000. This method has not yet been controlled as a quantitative procedure by any other observer, but deserves investigation.

Various synthetic adrenalins have been made, but while many give the chemical reactions of this body yet they do not have its physiological action.[a] Others have almost the same blood-pressure-raising properties as adrenalin. Thus the compound made by Dakin[b] caused a definite rise in blood pressure in rabbits with cut vagi, when injected in doses of 0.000001 gram.

The field of usefulness for the suprarenal glands in therapy is increasing,[c] but these preparations are being used almost with recklessness. Reports of toxic symptoms and secondary hemorrhage following their use are now appearing.[d]

In the case of animals it has been shown that the repeated intravenous injections of small doses of adrenalin will cause changes in the heart muscle (myocarditis)[e] and degeneration of the arterial walls resembling, if not identical with, arterio-sclerosis.

D'Amato[f] has made the interesting observation that arterial degeneration occurs from repeated use of small doses of suprarenal

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[a] Barger, G., and Jowett, H. A. D. Synthesis of substances allied to epinephrin. Jour. Chem. Soc. Trans., vol. 87, pt. 2, p. 967, 1905.

Stolz, F. Ueber Adrenalin und Alkylaminoacetobrenzcatechin. Ber. d. Deutsch. Chem. Gesells., vol. 37, pt. 4, p. 4149, 1905.

Friedman, E. Konstitution des Adrenalins. Beitr. z. Chem. Physiol. u. Path., vol. 8, p. 95, 1906.

Loewi, O., and Meyer, H. Ueber d. Wirkung synthetischer dem Adrenalin verwandter Stoffe. Arch. f. Exp. Path. u. Pharmakol., vol. 53, p. 213, 1905.

[b] Dakin, H. D. Synthesis of a substance allied to adrenalin. Proc. Roy. Soc. London, ser. B, vol. 76, p. 491, 1905.

On the physiological activity of substances indirectly related to adrenalin. Proc. Roy. Soc. London, ser. B, vol. 76, p. 498, 1905.

[c] Kreuzfuchs, S. Einige Erfahrung. über innere Adrenalindarreichung. Wien. Med. Presse, vol. 47, p. 922, 1906.

Oppenheim, R., and Loeper, M. La médication surrénale. Paris, 1904.

[d] Burnett, C. H. Results of a mistake in putting up a prescription for adrenalin chloride to be used as a nasal spray. Internat. Clinic, vol. 4, p. 25, 1902.

Roberts, L. M. Antidote for suprarenal preparations. Jour. Amer. Med. Assoc., vol. 47, p. 2159, 1906.

Potts, B. H. Danger from the careless use of the alkaloid of the suprarenal gland. Jour. Amer. Med. Assoc., vol. 47, p. 1188, 1906.

[e] Pearce, R. M. Experimental myocarditis: A study of the histological changes following intravenous injections of adrenalin. Jour. Exper. Med., vol. 8, p. 400, 1906.

[f] D'Amato, L. Weitere Untersuch. über d. von den Nebennierenextrakten bewirkten Veränderungen d. Blutgefässe. Berl. Klin. Woch., 1906, pp. 1100, 1131.

Elliott, T. R., and Durham, H. E. On subcutaneous injections of adrenalin. Jour. Physiol., vol. 34, p. 498, 1906.

NOTE.—Data on the effects on the urinary secretion can be found in Bardier, E., and Frenkel, H., Action de l'extrait capsulaire sur la diurèse et la circulation rénale, Jour. de Physiol. et de Path. Gén., vol. 1, p. 950, 1899.

preparations by mouth, which by this method of administration fail to produce any rise in blood pressure. Metabolic changes, shown by the presence of glycosuria, and histological changes, especially in the involuntary muscle fibers of the stomach and intestine, and changes in the liver cells have been noted in experimental work on animals,[a] so that it becomes imperative to exercise more care in the use of these preparations and to determine accurately the amount of the active principle used.

MEASUREMENT OF THE RISE OF BLOOD PRESSURE IN HIGHER ANIMALS.

At present the most satisfactory method of standardizing these preparations is by measuring the actual rise in blood pressure which follows the intravenous injection into animals of definite amounts of a solution of the pure active principle and comparing this rise with that produced by the same amount of the solution to be tested. The method is based on the fact that in the same animal the same amount of the active principle will produce the same rise in blood pressure, provided the conditions are unaltered.[b] The vagi nerves should first be cut or atropin injected to secure the full pressor effects of the injection. These measurements are usually made by

[a] Blum, F. Nebennierendiabetes. Deutsch. Arch. Klin. Med., vol. 71, p. 146, 1901.
Loeper, M., and Crouzon, O. L'action de l'adrénaline sur le sang. Arch. d. Méd. Expér., vol. 16, p. 83, 1904.
Paton, D. N. Effect of adrenalin on sugar and nitrogen excretion in the urine of birds. Jour. Physiol., vol. 32, p. 59, 1905.
Citron, J. Ueber d. durch Suprarenin experiment. erzeugt. Veränderungen. Zeits. f. Exper. Path. u. Ther., vol. 1, p. 649, 1905.
Drummond, W. B. Histological changes produced by the injection of adrenalin chloride. Jour. Physiol., vol. 31, p. 81, 1904.
Erb, W. Exper. u. histol. Studien über Arterienerkrankung nach Adrenalininjectionen. Arch. f. Exp. Path. u. Pharmakol., vol. 53, p. 173, 1905.
Herter, C. A., and Richards, A. N. Note on the glycosuria following experimental injections of adrenalin. Med. News, vol. 80, p. 201, 1902.
Wolownik, B. Exper. Untersuch. über d. Adrenalin. Arch. f. Path. Anat., vol. 180, p. 225, 1905.
Papadia, G. Arteriosclerosi da adrenalina. Rev. di Pat. Nerv., vol. 11, p. 113, 1906. [Contains bibliography.]
Biland, J. Ueber d. durch Nebennierenpräparate gesetzten Gefäss- und Organveränderungen. Deutsch. Arch. f. Klin. Med., vol. 87, p. 413, 1906.

[b] Houghton, E. M. Pharmacologic assay of preparations of the suprarenal glands. Amer. Jour. Pharm., vol. 73, p. 531, 1901; National Standard Dispensatory, Hare, Caspari, and Rusby, 1905, p. 1732.
Pharmacology of the suprarenal gland and a method of assaying its products. Jour. Amer. Med. Assoc., vol. 38, p. 150, 1902. [A solution of 1-10,000 was used.]
Franz, F. Aus exper. Arbeiten über Adrenalin, seine physiol. Werthbestimmung u. seine Wirkung. Sammelreferat. Med. Klinik, 1907, p. 99.
Battelli, M. F. Quantité d'adrénaline existant dans les capsules surrénales de l'homme. Compt. Rend. Hebd. Soc. de Biol., vol. 54, p. 1205, 1902.

means of the mercury manometer recording on the drum of a kymograph.

Animals preferred.—Dogs, on account of their greater resisting powers and their closer resemblance to man in responding to drugs, are usually preferred for this class of work, although rabbits are very serviceable. Cats are not so sensitive but are preferred by Elliott.

Principal reference literature.—Details regarding the preparation of the animal as to the mechanical carrying out of the experiment can be found in Essentials of Experimental Physiology, by T. G. Brodie, 1898, p. 168; Klein, Burton-Sanderson, and Brunton, Handbook for the Physiological Laboratory; T. Sollmann, Textbook of Pharmacology, 2d ed., 1906, pt. 3; Pembry, Beddard, Edkins, Hill, McLeod, and Pembry, Practical Physiology; E. Cyon, Methodik der physiologischen Experimente und Vivisection; O. Langendorff, Physiologische Graphik; Edmunds and Cushny, Laboratory Guide in Experimental Pharmacology; Hermann, Experimental Pharmacology; H. C. Wood, jr., Description of the Methods of Investigating the Action of Drugs, International Clinic, vol. 4, p. 12, 1902; D'Arsonval, Gabriel, Chaveau, and Marey, Traité de Physique Biologique; R. Tigerstedt, Lehrbuch der Physiologie des Kreislaufes.

Data concerning the anatomy of the dog, the rabbit, and the cat can be found in Ellenberger and Baum, Anatomie des Hundes; W. Krause, Anatomie des Kaninchens; St. George Mivart, The Cat.

The large Handbuch der experimentellen Pathologie und Pharmakologie of Heinz deals with results rather than with details of methods. There are, however, a few points which are not usually mentioned.

Apparatus.—We have been dissatisfied with the ordinary kymograph driven by a spring, on account of the variation in speed and the necessity for frequent winding. In the case of the expensive Hürthle machine this objection does not hold. For this reason the writer has used an electric kymograph—the one described by him in American Medicine, 1904, volume 8, page 405. This kymograph can be easily made in most machine shops, as the wheels are stock cut. The machine requires very little attention and the paper winds regularly and does not sag. The kymograph made by Blix[a] also overcomes many of the usual difficulties. The speed of the kymograph should be kept uniform and should be noted.

The time markers which have given the most satisfactory results are those described by Marvin[b] under the name "Magnet for recording sunshine and rainfall." This by slight modification can be made

[a] Blix, M. Neue Registrirapparate. Arch. f. Gesam. Physiol., vol. 90, p. 405, 1902.

[b] Marvin, C. F. Anemometry. U. S. Dept. Agr., Weather Bureau, Circ. D, Instrument Div., 2d ed., 1900, p. 47.

to write in a vertical position, and it records the seconds in steplike groups so that they can be counted off at a glance.

A very convenient manometer is the ordinary one of glass made into the form of a U. The internal diameter should be as near as possible to 4 mm., as at this width the least error occurs.[a] To the horizontal portion of the tube a small right-angular tube is sealed, and this is connected with the pressure bottle. At the end of the horizontal portion a small flexible lead tube is connected by means of thick-walled rubber tubing, and the opposite end of the lead tube connects with a wash-out cannula.

The most convenient form of wash-out cannula is the one which has been used in Professor Howell's laboratory for ten or fifteen years and consists of a metallic T tube. The long arm of the T is divided in its lower half by a longitudinal partition, which separates this part of the tube into two sections, one continuing on through the full length, the other communicating with the side arm of the T.[b] When this tube is inserted into the glass cannula and connected with the carotid artery a continuous stream of fluid will wash out any clots which may form.

In recording respiration the writer uses, when necessary, the chest tambour connected with an ordinary Marey tambour, writing directly upon the drum of the kymograph. The secret of obtaining good respiratory tracings lies in the use of extremely thin rubber. For this purpose rubber about as thin as tissue paper is best. For accuracy in reading pressures, a running base line is used. In commercial work where it is necessary to save time, the paper is further divided by a series of equidistant lines running parallel to the base line to facilitate reading off measurements. One adjusted to run at the level of normal pressure is especially desirable for rapid work.

As to the respiration apparatus, at present the most suitable one seems to be that of Meyer[c] because of the alternate force and suction pumps, but that of Hoyt,[d] which is merely a force pump, is very serviceable.

Preparation of animals for testing.—The animal should be carefully anæsthetized both for humanitarian reasons and to render it motionless, as any motion on the part of the animal would vitiate the results. If necessary, curare with morphin may be used to secure immobility; then artificial respiration will be required. While the use of chlore-

[a] Schaefer, E. A. Textbook of Physiology, vol. 2, p. 78.

[b] Hermann, L. Exper. Pharmacology, 1883, p. 101.

[c] Meyer, H. Zwei neue Laboratoriumsapparate. Arch. f. Exp. Path. u. Pharmakol., vol. 47, p. 426, 1902.

[d] Hoyt, J. T. Apparatus for artificial respiration. Jour. Physiol., vol. 27, p. 48, 1901.

tone has disadvantages, it is generally used for this class of work in dogs where the animal is not allowed to recover (0.2 gram per kilo is usually given in alcoholic solution after the hypodermic injection of morphin, or chloretone may be used alone). This does away with the use of a volatile anæsthetic.[a] After the use of large doses of chloretone alone the writer noted that while the animal may be merely drowsy after one hour, a few whiffs of ether will secure good anæsthesia, which will continue. Sometimes as anæsthesia sets in the animal ceases to breathe, but a few strokes of the respiration machine will soon restore the breathing, which will then continue of itself. In the case of rabbits, 3 grams of urethane may be given in solution by mouth, or 1.50 grams subcutaneously,[b] while cats should receive 1.25 grams per kilo. With this anæsthetic and kept on a warm table, the blood pressure in cats will remain at 130–140 mm. for hours.[c] Urethane is not suitable for dogs. Before connecting the animal to the kymograph it should be weighed, so that the necessary dose of adrenalin can be calculated.

Results obtained by various investigators.—Cameron[d] has shown that the smallest dose which gives a "definite and invariable rise" in blood pressure in rabbits weighing about 2,000 grams is 0.00062 mg., or 0.0003 mg. per kilo, or 0.00000031 gram per kilogram; that is, 0.5 c. c. of a 0.125 per cent solution of an adrenalin solution of 1 to 1,000, or 0.5 c. c. of a solution of 1 to 800,000 (1 c. c. of a 1–1,000 solution diluted to 800 c. c.).

In cats, which are more resistant than rabbits, Ehrmann[e] found that the intravenous injection of 0.1 mg. gave a rise which was just appreciable.

Abel's epinephrin bisulphate in 0.00013 gram caused a rise of 14 mm. Hg in a small dog with cut vagi,[f] and von Fürth's suprarenin iron compound in doses of 0.000017 gram per kilo (dog) caused the maximum rise, while 0.000075 gram caused a marked rise, 24 mm. Hg in rabbits (2 kilos).[g]

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[a] Impens, E. Chlorétone. Arch. Internat. de Pharmacodynamie, vol. 8, p. 77, 1901. Houghton, E. M., and Aldrich, T. B. Chloretone. Jour. Amer. Med. Assoc., vol. 33, p. 777, 1899.

[b] Schmiedeberg, O. Ueber d. pharmakol. Wirkungen u. d. therap. Anwend. einiger Carbaminsaure-ester. Arch. f. Exper. Path., vol. 20, p. 203, 1886.

[c] Elliott, T. R. Action of adrenalin. Jour. Physiol., vol. 32, p. 449, 1905.

[d] Cameron, I. D. On the methods of standardising suprarenal preparations. Proc. Roy. Soc. Edinburgh, vol. 26, p. 161, 1905.

[e] Ehrmann, R. Ueber eine physiol. Werthbestimmung des Adrenalins. Arch. f. Exp. Path. u. Pharmakol., vol. 53, p. 106, 1905. [Weight of animal not given.]

[f] Abel, J. J. Ueber d. blutdruckerregenden Bestandtheil der Nebenniere, das Epinephrin. Zeits. f. Physiol. Chem., vol. 28, p. 339, 1899.

[g] Von Fürth, O. Zur Kenntniss d. brenzkatechinähnlich. Substanz d. Nebennieren. Zeits. f. Physiol. Chem., vol. 29, pp. 115 and 112, 1900.

Epinephrin sulphate intravenously injected into atropinized dogs previously narcotized with morphin and ether produced a rise as follows:

0.083	millionth of a gram per kilo body weight, 5 mm. Hg.
0.23	millionth of a gram per kilo body weight, 7 mm. Hg.
0.49	millionth of a gram per kilo body weight, 15 mm. Hg.
0.69	millionth of a gram per kilo body weight, 20 mm. Hg.
1.7	millionth of a gram per kilo body weight, 24 mm. Hg.
5.7	millionth of a gram per kilo body weight, 66 mm. Hg.

Unfortunately, in these experiments the interval of time between the injections is not specified.[a]

In a dog weighing 4.5 kilos with a carotid pressure of 140 mm. Hg the intravenous injection of 0.02 mg. of adrenalin was followed by a rise of 46 mm. After the injection of atropin the same dose caused a rise of 50 mm.[b]

The normal blood pressure in rabbits as measured from the carotid artery is about 90 mm. Hg, but varies from 80 to 100.

Josué [c] noted that while frequently repeated intravenous injections caused a permanent rise in blood pressure, yet these animals still gave the characteristic abrupt rise in blood pressure on fresh injections—in other words, there was no immunity—and Elliott and Durham in three experiments with cats failed to find the presence of an anti-body.[d]

The normal blood pressure for dogs, as measured from the carotid artery, is 140 mm. and in rabbits 70 mm. of mercury,[e] while the maximum pressure according to Elliott is ±300 mm. for dogs, 180 mm. for rabbits, and 240 mm. for cats.

Oliver and Schaefer [f] have claimed that 0.015 gram per kilo of the fresh glands would cause the maximum rise in dogs (10 kilos).

In non-narcotized and non-curarized rabbits Pruszynski [g] noted a rise of 90 mm. Hg with 0.000047 gram per kilo of adrenalin. With

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[a] Hunt, R. On the effects of intravenous injections of minimal doses of epinephrin sulphate upon the arterial blood pressure. Proc. Amer. Physiol. Soc., p. vii; Amer. Jour. Physiol., vol. 5, 1901.

[b] Baylac, J. Recherches expér. sur les propriétés physiol. et toxiques de l'adrénaline. Arch. Med. de Toulouse, vol. 12, p. 265, 1905.

[c] Josué, O. La pression artérielle chez le lapin à la suites d'injections répétées d'adrénaline dans les veines. Comp. Rend. Hebd. Soc. de Biol., vol. 59, pt. 2, p. 319, 1905.

[d] Elliott, T. R., and Durham, H. E. On subcutaneous injections of adrenalin. Jour. Physiol., vol. 34, p. 490, 1906.

[e] Langendorff, O. Physiolog. Graphik., p. 204.

[f] Oliver, G., and Schaefer, E. A. Physiological effects of extracts of suprarenal capsules. Jour. Physiol., vol. 18, p. 235, 1895.

[g] Pruszynski, J. Influence of adrenalin on the circulatory system. Medicine, vol. 11, p. 924, 1905.

an intravenous injection of 1 c. c. of a 1–100,000 solution, Takamine obtained a rise of 30 mm. Hg in the case of a dog weighing 8 kilos, while in a dog weighing 15.5 kilos 0.000016 gram induced a rise of 9 mm.[a]

With a similar injection of 1 c. c. of a 1–10,000 solution, John[b] obtained a rise of 50 mm., registered by a Hürthle manometer, in a dog weighing 3½ kilos when the vagi were not cut. These results remained constant on repeating. If one vagus nerve was cut the pressure rose in one case 75 mm., and on repeating rose 60 mm. If both nerves were cut the pressure rose much higher—about 150 mm.

According to Toujan[c] 0.001 mg. of adrenalin will cause an appreciable rise in atropinized dogs weighing 10 kilos, a sensibility of 1–1,000,000, and Sollmann reports a rise of 14 mm. after the injection of 0.001 mg. per kilo. Carnot and Josserand obtained a maximum rise of 17.5 cm. Hg in a dog weighing 15 kilos with 0.000016 gram per kilo of adrenalin.[d]

A dog weighing 11.29 kilos anæsthetized with 0.3 gram of morphin intravenously after an injection into the vein of 0.001 gram of adrenalin gave a rise from 38 mm. normal to 128 mm. Hg. A second injection gave a rise from 36 mm. to 132 mm.[e] In Dupuis and Van den Eeckhart's hands an intravenuos injection of 1 c. c. of a 1–4,000 solution of adrenalin increased the blood pressure in the femoral artery 4 cm. Hg in a dog weighing 23 kilos, under morphin and atropin. This rise persisted 1½ minutes. One c. c. of a 1–1,000 solution produced a rise of 14 cm. This returned to normal in five minutes. The rise was followed by a hypotension of 1 cm. below normal.[f]

Sudden death may at times occur in dogs even from 0.12 mg. of adrenalin, although the rise in blood pressure may have been only small (32 mm.). In these cases the action seems to fall directly on the heart, as the respiration may continue after the heart stops.[g]

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[a] Takamine, J. Adrenalin, the active principle of the suprarenal glands. Amer. Jour. Pharm., vol. 73, p. 530, 1901; Therap. Gaz., vol. 25, p. 223, 1901.

[b] John, K. Nebennierenpräparate. Dissert., Leipzig, 1906, p. 17.

[c] Toujan, G. Recherches expér. sur l'adrénaline. Thèse, Toulouse, 1905, p. 36.

[d] Carnot, P., and Josserand, P. Les différences d'action de l'adrénaline sur la pression sanguine suivant les voies de pénétration. Comp. Rend. Hebd. Soc. de Biol., vol. 54, p. 1473, 1902.

[e] Reichert, E. T. Adrenalin, the active principle of adrenal extract. Univ. Pa. Med. Bul., vol. 14, p. 53, 1901.

[f] Dupuis and Van den Eeckhart. L'adrénaline. Ann. de Méd. Vét., vol. 52, p. 484, 1903.

NOTE.—Other figures may be found in Neujean, V., Contrib. à l'étude expér. de l'adrénaline, Arch. Internat. de Pharmacodynamie, vol. 13, p. 45, 1904.

[g] Elliott, T. R. Action of adrenalin. Jour. Physiol., vol. 32, p. 465, 1905.

Livon, C. Danger du principe actif des capsules surrénales dialysé. Comp. Rend. Hebd. Soc. de Biol., vol. 54, p. 1501, 1902.

In cats under urethane, 0.03 mg. of adrenalin produced the maximum rise.[a]

Subcutaneous injections[b] or administration per os usually produced no rise in blood pressure. The slight rise seen at times may be due to the local action on the stomach walls. Intramuscular injections are, however, followed by some rise,[c] and the effects vary with the mode of injection as to whether it passes through the hepatic circulation or through the muscles, etc.[d]

If the injection of small doses is rapidly repeated the rise in blood pressure with the same amount of active principle is slightly less but more persistent.[e] With medium doses the rise and its duration may be greater than from the first, but if a proper interval of time elapses between the injections the second rise will correspond to the first, an observation which is confirmed by Baylac.[f] For a dog of 8 kilos, five minutes' time is sufficient when using small doses—0.006 to 0.001 mg.[g] Josserand says there is no accumulation with 0.000016 mg. per kilo.[h]

If large doses are used, the pressure may stay high for a long time, then fall below normal,[i] and serious disturbances with the heart, shown by pericardial effusions, may occur and vitiate the result.[j] Weiss and Harris[k] have claimed that adrenalin can still be found in the blood even when the blood pressure has fallen to normal; thus after injecting 0.0034 gram of adrenalin into a cat weighing 3,000 grams and waiting thirty minutes, the transfused blood caused a rise of 15 mm. in a second cat. No control experiments with normal blood seem to have been made. Elliott, however, says that when the blood pressure

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[a] Elliott, T. R. Action of adrenalin. Jour. Physiol., vol. 32, p. 448, 1905.

[b] Reichert, E. T. Adrenalin. Univ. Pa. Med. Bul., vol. 14, p. 51, 1901.

[c] Meltzer, S. J., and Auer, J. Ueber d. Resorption aus den Muskeln. Zent. f. Physiol., vol. 18, p. 689, 1904.

[d] Carnot, P., and Josserand, P. Des différences d'action de l'adrénaline sur la pression sanguine suivant les voies de pénétration. Comp. Rend. Hebd. Soc. de Biol., vol. 54, p. 1472, 1902.

[e] Toujan, G. Recherches expér. sur l'adrénaline. Thèse, Toulouse, 1905, p. 37.

[f] Baylac, J. Recherches expér. sur le propriétés physiol. et toxique de l'adrénaline. Arch. Méd. de Toulouse, vol. 12, p. 252, 1905. [Used 10-minute interval for rabbits.]

[g] Toujan, G. Recherches expér. sur l'adrénaline. Thèse, Toulouse, 1905, p. 38.

[h] Josserand, P. Contrib. à l'étude physiol. de l'adrénaline. Thèse, Paris, 1904, p. 33.

NOTE.—See also Gioffredi, C., La distruezione dell' adrenaline nell' organismo, Archiv. di Farmacol. Speriment., vol. 6, pp. 127, 145, 1907.

[i] Battelli, F. Transformation de l'adrénaline dans l'organisme. Compt. Rend. Hebd. Soc. de Biol., vol. 54, p. 1518, 1902.

[j] Elliott, T. R. Action of adrenalin. Jour. Physiol., vol. 32, p. 444, 1905.

[k] Weiss, O., and Harris, J. Zerstörung des Adrenalins im lebenden Tier. Arch. f. Gesam. Physiol., vol. 103, p. 510, 1904.

Harris, J. Dissert., Königsberg, 1904.

Battelli, F. Transformation de l'adrénaline dans l'organisme. Compt. Rend. Hebd. Soc. de Biol., vol. 54, p. 1519, 1902.

has returned to normal in the cat, the substance has then disappeared almost entirely from the blood. Elliott's table showing the effects of injecting smaller doses gives the different results obtained:

CAT (VAGI CUT).

Time.	Treatment.	Results.
11.45.	Received 0.18 mg. adrenalin.	Blood pressure rose 150 to 220 mm. Hg.
11.48.	Received 0.30 mg. adrenalin.	Blood pressure rose 130 to 230 mm. Hg.
11.56.		Blood contained no demonstrable adrenalin.
12.05.	Received 0.3 mg. adrenalin.	Blood pressure rose 145 to 220 mm. Hg.
12.08.	Received 0.6 mg. adrenalin.	Blood pressure rose 110 to 210 mm. Hg.
12.14.	Received 0.6 mg. adrenalin.	Blood pressure rose 130 to 220 mm. Hg.
12.22.	Received 0.6 mg. adrenalin.	Blood pressure rose 120 to 206 mm. Hg.
12.26.		Blood contained no adrenalin.
12.40.	Received 1 mg. adrenalin.	Blood pressure rose 110 to 200 mm. Hg.
12.46.	Received 1 mg. adrenalin.	Blood pressure rose 140 to 178 mm. Hg.
12.50.		Pupils still dilated. Blood pressure 150 mm. Hg.
1.17.	Received 1 mg. adrenalin.	Blood pressure rose 95 to 170 mm. Hg.
1.21.	Received 1 mg. adrenalin.	Blood pressure rose 130 to 156 mm. Hg.
1.24.	Received 1 mg. adrenalin.	Blood pressure 140; no rise.
1.25.		Adrenalin found in blood. Five c. c. contained 0.02 mg.
1.45.	Received 1 mg. adrenalin.	Blood pressure rose 60 to 115 mm. Hg.
1.48.		No demonstrable adrenalin.

Control cat showed 0.01 mg. in 5 c. c.

In comparing the strengths of solutions it should be remembered that because 1 c. c. of a solution gave a rise of 17 mm. Hg, 2 c. c. will not necessarily double this rise; in fact, while there is a general increase with increasing doses up to a certain limit, we are unable to find any mathematical relationship between the rise in blood pressure and the dose. Thus Toujan in a dog narcotized with chloralose and atropinized (1cgm. per 7 kilos), injected 1 c. c. of a suprarenal extract containing 0.001 mg. per cubic centimeter and obtained a rise of 17 mm. After five-minute intervals—

Injected 2 c. c. and obtained a rise of 19.5 mm.
Injected 3 c. c. and obtained a rise of 25.0 mm.
Injected 4 c. c. and obtained a rise of 23.0 mm.
Injected 5 c. c. and obtained a rise of 25.0 mm.

The persistency of the rise gives a better idea as to the intensity of the action; thus, using a drum which traveled at a rate of 0.28 cm. per second, after injecting 1 c. c. of the solution specified the drum traveled 30 mm. before the blood pressure returned to its original level—

After 2 c. c. it traveled 40 mm.
After 3 c. c. it traveled 102 mm.
After 4 c. c. it traveled 130 mm.
After 5 c. c. it traveled 150 mm.

Young dogs are claimed to be more responsive to adrenalin than older dogs having the same weight.[a]

The quantitative work which has been carried on with adrenalin has been performed with the adrenalin of commerce. This was shown to contain extraneous matter (phosphates)[b], as one would expect from the method of isolation described by Takamine, so that it does not seem rational to standardize against a body which is not chemically pure and which the manufacturers themselves do not label as c. p. The standard used should be the highest grade of active principle known. Abel's latest method, as acknowledged by Pauly[c], or adrenalin as prepared by Aldrich's method seems to answer this demand. This adrenalin (Aldrich's) can perhaps be obtained from the manufacturers, but at a higher price. A supply of this high grade adrenalin (epinephrin) should be kept on hand in a vacuum desiccator and preserved in the dark. When the test is to be made, a few milligrams of this are accurately weighed off and dissolved in water with a little over the calculated amount of HCl $\frac{N}{10}$, constantly shaking,[d] and made up in a proportion of 1 to 50,000, the solution placed in a Florence flask and gently heated on the bath to body temperature (37½° C.). One-half of a cubic centimeter of this solution would correspond to 0.001 mg. per kilo for a dog of 10 kilos. One-half of a cubic centimeter of this warm solution is then

[a] Josserand, P. Contrib. à l'étude physiol. de l'adrénaline. Thèse, Paris, 1904, p. 31.

[b] Abel, J. J. On a simple method of preparing epinephrin and its compounds. Bul. Johns Hopkins Hospital, vol. 13, p. 30, 1902. Prof. Abel says: "I judge from the bulkiness of the phosphomolybdate precipitate that a quantitative experiment would result in a high percentage of impurity. * * * Commercial adrenalin was * * * purified * * * and more than thirty analyses of various fractions have been made, but it has been found impossible to secure uniformity of composition among the various products."

Function of the suprarenal glands. Contributions to Med. Research, dedicated to V. C. Vaughan, p. 155.

Compare also Gunn, A., and Harrison, E. F. A new characteristic reaction of adrenaline. Pharm. Jour., 1907, p. 718.

[c] Abderhalden, E., and Bergell, P. Münch. Med. Woch., vol. 51, p. 1003, 1904.

[d] Takamine says "100 parts of adrenalin needs nearly 19 parts of hydrochloric acid in forming a neutral salt." (Amer. Jour. Pharm., vol. 73, p. 527, 1901.)

injected by means of a small calibrated syringe and connections into the saphenous vein. The time of this injection should be registered and should occupy about five seconds, and should be gently performed. This is then rapidly followed from the same syringe with 1 c. c. of the normal salt solution to wash into the circulation any of the solution that may be in the syringe and connections. This injection should occupy the same length of time and should always be noted. It is important that the standard solution be made fresh at each test, as otherwise it gradually loses its activity. The pupils should be examined to see if there is any action, as there may be bodies present in the extract which might neutralize the blood-pressure-raising action. During the experiment the animal must be kept warm. Not over 2 c. c. of fluid should be injected at any one time, to avoid the pressor action of the large volume of fluid. The action of the comparatively large amounts of fluid used in this form of injection may be overcome by injecting the fluid into the vein without the use of a syringe. For this injection a pipette of 1 c. c. capacity accurately divided into tenth cubic centimeters is closely connected to a fine, clean, sharp hypodermic needle by means of a rubber tube, and after gently pushing the needle through the wall of the vein toward the heart the fluid is let run into the circulation and the amount controlled by the finger or, better, a burette may be connected with the cannula and the injection thus made. By this method it will not be necessary to use sodium chlorid solution to wash the adrenalin solution into the vein.

The most satisfactory method is to connect the syringe or, preferably, a burette containing the standard solution with one saphenous vein and the solution to be tested with the corresponding vein of the other leg, so that alternate injections of standard and unknown solution can be made under the same conditions. The writer's own preference is for the burette method.

The maximum rise in blood pressure from this injection, 0.001 mg. per kilo, which is about 14 to 28 mm. Hg, although this will vary in various dogs, is now noted, and also the distance traveled by the paper and the time which elapses before the blood pressure returns to normal. A line running on a level with the base of the blood pressure curve will aid in rapid calculation. The method of measuring the blood pressure can be found in W. Stirling's Outlines of Practical Physiology, third edition, 1898, page 305.

Very dilute solutions are purposely used, so that there will be no accumulation of the active principle in the animal. After five or six minutes a very dilute solution, one which would approximate in strength that of the normal, and diluted to the same bulk as the control, is similarly injected, with all the above precautions, and the

maximum blood pressure and the time which elapses before the blood pressure returns to normal is likewise noted and compared with the standard. At intervals of five or six minutes various amounts of this fluid are injected, until an amount is injected which gives a rise which corresponds to the 1 c. c. of the standard solution. This injection should be repeated several times, changing the order of the injection, and a mean taken, and finally the correct solution and the standard one injected into a fresh dog which has had no fluid injected. By comparing the strength of the two solutions the actual number of milligrams present can be determined. Thus, if in 1 c. c. of the standard solution there were 0.01 mg. and this gave a rise of 14 mm. of Hg, and if 2 c. c. of a similar dilute solution of the unknown gave the same rise, we would naturally argue that the second solution was one-half the strength of the first and contained 0.005 mg. per c. c. The solutions of the unknown can then be adjusted, so as to use the same amount of fluid of the standard and the test controlled, reversing the order of the injections. It is advisable to repeat the injections several times, checking these results repeatedly.

Elliott[a] advises against using over 0.03 mg. Dale, using cats according to Elliott's method, is said to measure epinephrin solutions within about 5 per cent.[b]

Cameron,[c] struck with the work of Marshall on the antagonism of the members of the digitalis series with the nitrites, extended these observations to the antagonism between the nitrites and adrenalin and found that 0.6 mg. ($\frac{1}{100}$ gr.) of nitroglycerin would require 0.0075 mg. of adrenalin to neutralize its vasodilator action in a rabbit weighing 2,000 grams anæsthetized with ether. This method he considers even more satisfactory than the simple blood pressure measuring, especially if there is not a reliable standard preparation to standardize against. One example from Cameron will illustrate. The minimal effective dose of a 1 per cent solution was 0.5 c. c. The minimal effective dose of an adrenalin solution had been found to be 0.00062 mg. for rabbits of 2,000 grams weight; hence, 0.005 c. c. of the solution = 0.00062 mg. adrenalin, or 1 c. c. = 0.12 mg. By the nitrite method 0.6 mg. is neutralized by 0.7 c. c. of 10 per cent; this amount of nitroglycerin is neutralized by 0.5 c. c. of 1.5 per cent adrenalin solution (0.0075 mg.); therefore, 1 c. c. = 0.107 mg. This solution was one-tenth stronger than adrenalin chlorid, 1–1,000.

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[a] Elliott, T. R. Action of adrenalin. Jour. Physiol., vol. 32, p. 448, 1905.

[b] Barger, G., and Ewins, A. J. Note on the molecular weight of epinephrin. Chem. News, vol. 93, p. 90, 1906.

[c] Cameron, I. D. On the methods of standardising suprarenal preparations. Proc. Roy. Soc. Edinburgh, vol. 26, p. 170, 1906.

Ott and Harris[a] had tried this antagonistic action of these two bodies, but did not push the matter as far as Cameron. A similar antagonism with cholin had been pointed out by Lohmann.[b] After having determined the amount of active principle on the dog, rabbit, or cat by the simple blood pressure method, as a check to this method it may be advisable to inject the amount of the unknown solution corresponding to 0.0075 mg. adrenalin mixed with a solution of 0.6 mg. nitroglycerin into the jugular vein of a rabbit. I do not consider this additional test necessary, but the results of Cameron are certainly worth controlling.

Gürber[c] pointed out the presence of a depressor body in the suprarenal extracts. A portion of this action may be due to cholin and a portion to unknown bodies.[d] Extracts containing these depressor bodies are especially toxic. In crude extracts the depressor action of these bodies, and also of certain inorganic salts, should be kept in mind.

At the end of the experiment the animal should be killed by injecting chloroform into the veins, so that the most humane person could find no objection on the score of cruelty.

In the case of a mixture of adrenalin and peptone the action of one follows that of the other, and it is therefore unsuited for antagonistic study.[e]

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[a] Ott, I., and Harris, S. B. Physiological action of adrenalin chloride. Therap. Gaz., vol. 27, p. 378, 1903.

[b] Lohmann, A. Cholin, die den Blutdruck erniedrigende Substanz der Nebenniere. Arch. f. Gesam. Physiol., vol. 108, p. 222, 1907.

[c] Metzger, L. Zur Kenntniss d. wirksam. Substanzen d. Nebenniere. Dissert., Würzburg, 1897, p. 17.

[d] Hunt, R. Further observations on the blood pressure lowering bodies in extracts of the suprarenal glands. Proc. Amer. Physiol. Soc., Amer. Jour. Physiol., vol. 5, p. vi, 1901.

Marino-Zuco, F., and Dutto, U. Chem. Untersuch. ü. die addison'sche Krankheit. Untersuch. z. Naturlehre. Herausg. von J. Moleschott, vol. 14, p. 617, 1892.

Lohmann, A. Cholin, die den Blutdruck erniedrigende Substanz der Nebenniere. Arch. f. Gesam. Physiol., vol. 108, p. 215, 1907.

Pari, G. A. Azione locale dell' adrenalina sulle pareti dei vasi, ed azione delle minime dose di adrenalina sulla pressione del sangue. Arch. di Farmacol. Speriment., vol. 4, p. 175, 1905.

Vincent, S. Nature of the physiologically active substances in extracts of nervous tissues and blood, with some remarks on the methods of testing for cholin. Jour. Physiol., vol. 30, p. 143, 1904.

[e] Hamburger, W. W. Action of intravenous injections of glandular extracts and other substances upon the blood pressure. Amer. Jour. Physiol., vol. 11, p. 282, 1904.

In the report made to the Council on Pharmacy and Chemistry of the American Medical Association, no attempt was made to check up the results with the rise obtained from a definite amount of pure adrenalin, but only to compare the activity of the preparation on the market. Sollmann and Brown wisely remark that their results give no idea as to the activity of the preparations before leaving the manufacturers' hands.[a]

An interesting commercial problem is to see by what means the yield of adrenalin can be increased. Toujan has claimed that in the products of auto-digestion of pancreas there is a body (not tyrosin) which added to the ground-up suprarenals does this,[b] while Halle has found that the addition of tyrosin to the ground-up suprarenals caused in some cases an increase in the adrenalin yield.[c] Others claim that the addition of ground-up muscle added to suprarenal extract does the same.[d]

TOXICITY OF THE ACTIVE PRINCIPLE.

The following data on the toxicity of adrenalin may be of use:

The lethal dose for frogs is over 0.50 mg. per kilo. The relatively large amount necessary to kill is due to the fact that pulmonary respiration in frogs is not indispensable. In animals death is usually due to pulmonary œdema and an action on the heart.

The subcutaneous injection of 0.01 gram per kilo kills guinea pigs, but 0.004 gram rarely.

In rabbits 0.02 gram per kilo given hypodermically is fatal.[e] Baylac gives the immediate toxicity by this method as 1 cg. per kilo for rabbits and guinea pigs. One milligram adrenalin subcutaneously injected in rabbits weighing 400 grams rapidly kills.[f] On the intravenous injection into rabbits, 0.0006 gram per kilo is always fatal,[g] while three out of four die from 0.0004 gram per kilo. The imme-

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[a] Sollmann, T., and Brown, E. D. Comparative physiologic activity of some commercial suprarenal preparations. Jour. Amer. Med. Assoc., vol. 47, p. 792, 1906.

NOTE.—Compare also Hunt, R., Comparative physiologic activity of some commercial suprarenal preparations, in Jour. Amer. Med. Assoc., vol. 47, p. 790, 1906.

[b] Toujan, G. Recherches expér. sur l'adrénaline. Thèse, Toulouse, 1905, p. 67.

[c] Halle, W. L. Ueber d. Bildung d. Adrenalins im Organismus. Beitr. z. Chem. Physiol. u. Path., vol. 8, p. 276, 1906.

[d] Abelous, G. E., Soulié, A., and Toujan, G. Influence des extraits des organes et des tissus animaux soumis a l'autolyse sur la production de l'adrénaline. Comp. Rend. Hebd. Soc. de Biol., vol. 60, p. 16, 1906.

[e] Taramasio, P. Étude toxicol. de l'adrénaline. Thèse, Genève, 1902, p. 30.

[f] Paton, D. N. Effect of adrenalin on sugar and nitrogen excretion in the urine of birds. Jour. Physiol., vol. 32, p. 62, 1905.

[g] Battelli, F. Toxicite de l'adrénaline en injections intraveineuses. Comp. Rend. Hebd. Soc. de Biol., vol. 54, p. 1247, 1902.

diate toxicity by vein in rabbits (2 kilos) is 0.06 milligrams per kilo.[a] In dogs from 0.1 to 0.2 mg. per kilo intravenously injected kills, while in cats from 0.5 to 0.8 are sufficient.[b] Twenty milligrams adrenalin subcutaneously injected in cats caused no disturbance until the following day (Elliott).

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[a] Baylac, J. Recherches expér. sur les proprietes physiol. et toxiques de l'adrénaline. Arch. Méd. de Toulouse, vol. 12, p. 247, 1905.

[b] Lesage, J. Recherches expér. sur l'adrénaline. Arch. Internat. de Pharmacodyn., vol. 13, p. 273, 1904.

NOTE.—See also Amberg, S., Toxicity of epinephrin, in Proc. Amer. Physiol. Soc., p. XXXIII, Amer. Jour. Physiol., vol. 8, 1903.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 113.

B. T. GALLOWAY, *Chief of Bureau.*

THE COMPARATIVE TOLERANCE OF VARIOUS PLANTS FOR THE SALTS COMMON IN ALKALI SOILS.

BY

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PHYSIOLOGIST IN CHARGE OF ALKALI AND DROUGHT RESISTANT PLANT BREEDING INVESTIGATIONS,

AND

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ASSISTANT PHYSIOLOGIST, ALKALI AND DROUGHT RESISTANT PLANT BREEDING INVESTIGATIONS.

ISSUED OCTOBER 25, 1907.

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ALKALI AND DROUGHT RESISTANT PLANT BREEDING INVESTIGATIONS.

SCIENTIFIC STAFF.

Thomas H. Kearney, *Physiologist in Charge*.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., July 15, 1907.

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 113 of the series of this Bureau the accompanying technical paper, entitled "The Comparative Tolerance of Various Plants for the Salts Common in Alkali Soils," by T. H. Kearney and L. L. Harter.

The results of this work show clearly that different genera and species of plants differ greatly in their power of resistance to a given mixture of alkali salts and that marked differences in resistance also exist between different individuals of the same strain or variety, proving, therefore, that there is a good opportunity for increasing this quality by the artificial selection of resistant strains. The work also shows clearly that a strain made resistant to one combination of salts may not be resistant to another combination. The results are therefore important to those engaged in the selection and improvement of crops for alkali soils.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE COMPARATIVE TOLERANCE OF VARIOUS PLANTS FOR THE SALTS COMMON IN ALKALI SOILS.

INTRODUCTION.

In Report No. 71 of the Department of Agriculture[a] an account was given of the results of experiments upon the toxicity of certain salts of magnesium and sodium to young seedlings of the white lupine and of alfalfa. It was shown that these salts differ greatly in their toxicity when allowed to act upon the plants in pure solutions (i. e., of a single salt), but that the presence of a second salt, notably calcium sulphate, not only greatly increases the endurable concentration of the more toxic salt, but tends to equalize the toxicity of the different salts. Experiments, the results of which have not hitherto been published in full,[b] were afterwards made with maize, and it was found that not only were the critical concentrations of the same salts very different from those previously worked out for the white lupine, but the order of toxicity of the various salts also differed widely. The results obtained by Harter[c] with nine varieties of wheat show that not only are the critical concentrations for this plant different from those previously established for the white lupine and for maize, but that inside the limits of a species there can be much difference between different varieties in their power of resistance to toxic action.

Since the publication of this last paper similar experiments have been made with four varieties of sorghum (*Andropogon sorghum*), two varieties of oats (*Avena sativa*), two species of cotton (*Gossypium barbadense* and *G. hirsutum*), and sugar beets (*Beta vulgaris*). A majority of the more important field crop plants grown in parts of the United States where alkali soils occur are thus represented in the whole series of experiments.[d]

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[a] Some Mutual Relations Between Alkali Soils and Vegetation, 1902.

[b] Although referred to in a brief note in Science, n. s., vol. 17, p. 386, 1903.

[c] Bul. 79, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905.

[d] The white lupine was selected for the first experiments, not because it is of any importance as a crop plant in this country, but because of the ease with which it is handled in water-culture experiments.

The results have established the fact that different genera and species differ greatly in their power of resistance to the salts of magnesium and sodium that are common in so-called alkali soils, and that furthermore different varieties, or even mere agricultural strains of the same species, possess marked differences in this respect. In mixed solutions, especially in the presence of a salt of calcium, these differences are much less pronounced, but still exist in such a degree as to leave no escape from the conclusion that some species and varieties of plants are better adapted than others to growing in soils containing relatively large amounts of these salts. Since very marked differences in tolerance exist between different individuals of the same strain or variety, there is obviously an opportunity for an increase of this quality by artificial selection.

In the present paper the results of experiments with single (pure) solutions in their effect upon maize, sorghum (four varieties), oats (two varieties), cotton (two species), and sugar beets are first described. The resistance to pure solutions of these plants and of the white lupine, alfalfa, and wheat are next compared. The effect of an excess of calcium sulphate in neutralizing the toxicity of the magnesium and sodium salts upon each of the plant species above mentioned, and finally that of amounts of calcium sulphate smaller than an excess in counteracting the toxic effect of these salts upon the white lupine and upon sorghum are then treated.

It should be emphasized that the results of these water-culture experiments with pure solutions of a single salt or of two salts are not to be directly compared with the results of observations made upon plants growing in natural "alkali" soils. In the latter case we have always to deal with a mixture of several salts, and, moreover, the presence of the soil itself introduces physical factors that modify in various ways the effect of the solution upon plants. In these laboratory experiments the problem was purposely simplified by omitting the soil, thus permitting us to ascertain directly the varying toxic effect upon different plants of some of the principal "alkali" salts as a necessary preliminary to the more complex problem of their toxicity in the presence of the soil itself. In the experiments with mixed solutions a step is taken in the direction of this greater complexity, and it is noteworthy that the results obtained are in this case more nearly comparable with the relations obtaining in nature than are those with pure solutions. Experiments are now in progress in which cultures in sand watered with the extracts from natural alkali soils and with solutions of salts made up to imitate the alkali soil extracts, as well as in the natural alkali soils themselves, are substituted for the water cultures used in the experiments here described.

EXPERIMENTAL METHODS.

The methods used were described at considerable length in two previous publications upon this subject.[a] It suffices here to state that the effect upon the rapidly elongating portion (10 to 20 mm.) of the tips of the radicles of young seedlings was alone studied, inability to further elongate when transferred to pure water after twenty-four hours' exposure to the salt solution being taken as an indication that the concentration used was fatal to the root tips. The strength of solution which permits the root tips of about half the total number of seedlings used to survive this test is taken as the critical concentration.[b] The results are stated throughout in terms of fractions of normal solutions.

RESULTS WITH PURE SOLUTIONS.

RESULTS WITH MAIZE (ZEA MAYS).

TABLE I.—*Limits of endurance of maize seedlings of salts of sodium and magnesium.*

Salts used.	Critical concentrations.	Salts used.	Critical concentrations.
Sodium carbonate	0.015 normal	Sodium bicarbonate	0.05 normal
Sodium chlorid	.04 normal	Magnesium chlorid	.08 normal
Sodium sulphate	.05 normal	Magnesium sulphate	.25 normal

RESULTS WITH COTTON (GOSSYPIUM).

The Jannovitch Egyptian variety of cotton (*Gossypium barbadense*) and the Griffin Upland variety of cotton (*G. hirsutum*) were selected for these experiments.

[a] Kearney and Cameron, in Report No. 71, U. S. Dept. of Agriculture, pp. 13 to 18; and Harter, in Bul. 79, Bureau of Plant Industry, U. S. Dept. of Agriculture, pp. 16 to 23.

[b] The objection has been made to this method that the period of growth is too short and that the effect upon the root tip does not necessarily represent the effect upon the plant as a whole. Since, however, the purpose of these experiments is merely to obtain a simple and ready means of comparison of the toxicity of different salts to different plants under identical conditions and not a measure of the absolute limit of concentration that will permit the growth to maturity of plants of a given species, it is believed that the method used answers every purpose of this investigation. When the period is extended and the effect upon the whole plant is taken into consideration so many disturbing factors are introduced that reliable results become difficult if not impossible. Furthermore, since the conditions of these experiments are confessedly artificial—pure salt solutions rarely, if ever, occurring in nature—little would be gained by working out the limits of endurance for the entire plant during a long period of growth. In the experiments with soil cultures now in progress the effect of the salts upon the growth of the whole plant during a period of several weeks is taken into account.

TABLE II.—*Limits of endurance of cotton seedlings of salts of magnesium and sodium.*

Salts used.	Critical concentrations.	
	Gossypium barbadense.	Gossypium hirsutum.
Magnesium sulphate	0.000312 normal	0.000312 normal
Magnesium chlorid	.0004 normal	.000312 normal
Sodium carbonate	.005 normal	.0025 normal
Sodium sulphate	.005 normal	.005 normal
Sodium bicarbonate	.00625 normal	.00375 normal
Sodium chlorid	.00625 normal	.005625 normal

The most marked difference in resistance between the two species of Gossypium appears in the presence of sodium carbonate and sodium bicarbonate. Egyptian cotton (*Gossypium barbadense*) can endure twice as concentrated a solution of the carbonate and nearly twice as concentrated a solution of the bicarbonate as can Upland cotton (*G. hirsutum*). In resistance to magnesium chlorid and to sodium chlorid, also, *Gossypium barbadense* is slightly superior to *G. hirsutum.*

RESULTS WITH SORGHUM (ANDROPOGON SORGHUM).

Four different varieties of *Andropogon sorghum*, designated by the popular names of the varieties, were tested.

TABLE III.—*Limits of endurance of sorghum seedlings of salts of magnesium and sodium.*

Salts used.	Critical concentrations.			
	Early Amber.	Dwarf Milo.	Edra.	Dagdi Juar.
Magnesium chlorid	0.00625 normal	0.00375 normal	0.003 normal	0.00125 normal
Magnesium sulphate	.0085 normal	.00625 normal	.00625 normal	.00375 normal
Sodium carbonate	.00625 normal	.0075 normal	.007 normal	.00625 normal
Sodium bicarbonate	.009 normal	.0125 normal	.01 normal	.00875 normal
Sodium sulphate	.015 normal	.013 normal	.0125 normal	.0125 normal
Sodium chlorid	.018 normal	.014 normal	.015 normal	.015 normal

The difference in toxicity between sodium chlorid and sodium sulphate is hardly appreciable in the case of this plant. In the presence of magnesium chlorid there is more difference in resistance between the different varieties than in the presence of magnesium sulphate.

All except the Early Amber variety can endure a greater concentration of sodium carbonate than of magnesium sulphate, and with this exception the order of toxicity of the different salts is that given in the table.

The Dwarf Milo variety of sorghum is on the whole less resistant to the toxic influences of the various salts than the Early Amber. Magnesium chlorid brings out the most noticeable difference in this respect, the Early Amber showing as much resistance to a concentration of 0.00625 normal of this salt as the Dwarf Milo does to 0.00375 normal. To sodium bicarbonate the Dwarf Milo is more resistant than the Early Amber. To the other salts the two varieties are almost equally resistant.

The Edra variety is slightly less resistant than the preceding variety. It will be noticed that this variety, as well as the Dwarf Milo, can endure a greater concentration of sodium bicarbonate than the Early Amber, although the latter is the variety that is most resistant to most of the salts. Of magnesium chlorid a concentration of 0.00625 normal is critical for the Early Amber variety, which is more than twice the concentration that is critical for the Edra variety, and five times that which is critical for the Dagdi Juar variety. The last is decidedly the most sensitive of the four varieties. The Edra is somewhat more resistant than the Dwarf Milo to sodium chlorid, but the variation in resistance to this salt, as well as to sodium sulphate, is very slight with all the varieties.

In the case of *Andropogon sorghum* as in that of Triticum the greatest difference in resistance among the different varieties is shown in the presence of the more harmful salts. To the less harmful salts—for example, the chlorid and sulphate of sodium—there is less variation in resistance.

RESULTS WITH OATS (AVENA SATIVA).

TABLE IV.—*Limits of endurance of oat seedlings of salts of magnesium and sodium.*

Salts used.	Critical concentrations.	
	Red Algerian.	Culbertson.
Magnesium sulphate	0.001875 normal	0.000625 normal
Magnesium chlorid	.001875 normal	.0005 normal
Sodium carbonate	.00625 normal	.0075 normal
Sodium bicarbonate	.0075 normal	.009 normal
Sodium sulphate	.0175 normal	.015 normal
Sodium chlorid	.02 normal	.015 normal

The Red Algerian variety of *Avena sativa* can endure a concentration of magnesium sulphate three times as great as that which is critical for the Culbertson variety. There is about the same amount of difference in resistance to magnesium chlorid, the Red Algerian being again the more resistant. The Algerian variety is more resistant than the Culbertson to every salt except two (sodium carbonate and bicarbonate), and in these cases the difference is but slight. It is interesting to note that the former variety, which came originally from Algeria, where it is said to be grown successfully in soils containing a considerable amount of harmful salts, shows also a greater power of resistance to salts in pure solutions.

RESULTS WITH SUGAR BEETS (BETA VULGARIS).

The "Original Kleinwanzleben" strain of the sugar beet was selected for use in these experiments.

TABLE V.—*Limits of endurance of sugar-beet seedlings of salts of magnesium and sodium.*

Salts used.	Critical concentration.	Salts used.	Critical concentration.
Magnesium sulphate	0.0005 normal	Sodium bicarbonate	0.0075 normal
Magnesium chlorid	.0005 normal	Sodium sulphate	.00875 normal
Sodium carbonate	.00625 normal	Sodium chlorid	.025 normal

To the sugar beet sodium sulphate in pure solution is three times as toxic as sodium chlorid and only a little less toxic than sodium carbonate. The two magnesium salts are more than ten times as toxic as is sodium carbonate.

COMPARISON OF RESULTS WITH EIGHT SPECIES IN PURE SOLUTIONS.

In Table VI are brought together the results with pure solutions for all the species of plants so far investigated, the figures given being in each case the fraction of a normal solution representing the concentration of solution that allows the root tips of about one-half the total number of seedlings tested to retain their capability of further elongation after twenty-four hours of exposure to the solution.

TABLE VI.—*Critical concentrations of pure solutions for eight species of plants.*

Salts used.	Plants tested.								
	Lupinus albus (white lupine).*		Medicago sativa (alfalfa).	Triticum vulgare (wheat).	Zea mays (maize).	Andropogon sorghum (sorghum).	Avena sativa (oats).	Gossypium barbadense (cotton).	Beta vulgaris (beet).
	Series 1.	Series 2.							
Magnesium sulphate	0.00125	0.007	±0.001	0.005	0.25	0.00375	0.001875	0.000312	0.0005
Magnesium chlorid	.0025	.0075	± .002	.005	.08	.00125	.001875	.0004	.0005
Sodium carbonate	.005	.0125	....	.0125	.015	.00675	.00625	.005	.00625
Sodium sulphate	.0075	.04	....	.04	.05	.0125	.0175	.005	.00875
Sodium chlorid	.02	.045	....	.045	.04	.015	.02	.00625	.025
Sodium bicarbonate	.02	.03	....	.025	.05	.00875	.0075	.00625	.0075

*The experiments with *Lupinus albus* by Kearney and Cameron that were described in Report No. 71 of the United States Department of Agriculture, and of which the results are given in the column headed "Series 1" of Table VI, were repeated two years later by Harter, using a fresh lot of white lupine seed which, like the first, was obtained from Vilmorin, Andrieu & Co. in Paris. The critical concentrations worked out in this second series of experiments (as shown in the table) are much higher than those obtained in the first experiments. That this was largely due to the use of fresher seed was proved by repeating the experiments a third time, using seed of the same importation as that in series 2, but a year older. In this third series of experiments the results agreed more closely with series 1 than with series 2, the critical concentrations having been determined as follows: Magnesium sulphate, 0.002 normal; magnesium chlorid, 0.0025 normal; sodium carbonate, 0.0125 normal; sodium sulphate, 0.02 normal; sodium chlorid, 0.0175 normal; sodium bicarbonate, 0.015 normal. The order of toxicity of the different salts is very nearly the same in the three series, the principal difference being that in the second and third sodium chlorid is slightly more toxic than sodium sulphate, and sodium bicarbonate than sodium sulphate and chlorid. It is noteworthy that the critical concentrations in mixed solutions (containing calcium sulphate) were practically the same with the second lot of seed, even when fresh, as with the first, notwithstanding the great differences in the resistance of the two lots to pure solutions (see the second note to table on page 15).

The limits for *Medicago sativa* in pure solutions were worked out for the two magnesium salts alone, and with these the results are only approximate. Those for *Triticum vulgare* were obtained by Harter with the Chul variety of wheat. In the case of *Andropogon sorghum*

the limits for the Dagdi Juar variety are given; in that of *Avena sativa*, those for the Red Algerian variety of oats; in that of *Gossypium barbadense*, those for the Jannovitch Egyptian variety of cotton, and in that of *Beta vulgaris*, those for the Original Kleinwanzleben strain of sugar beets.

A glance at Table VI shows that not only do the different species differ vastly in the absolute degree of their resistance to the toxic action of these pure solutions, but the order of toxicity of the several salts varies considerably with respect to different species. For convenience of comparison, the order of toxicity of the six salts to each of the eight species is stated in Table VII.

TABLE VII.—*Order of toxicity of the different salts to each plant.*

Lupinus albus.	Medicago sativa.	Triticum vulgare.	Zea mays.	Andropogon sorghum.	Avena sativa.	Gossypium barbadense.	Beta vulgaris.
$MgSO_4$	$MgSO_4$	$MgSO_4$*	Na_2CO_3	$MgCl_2$	$MgSO_4$*	$MgSO_4$	$MgSO_4$*
$MgCl_2$	$MgCl_2$	$MgCl_2$*	$NaCl$	$MgSO_4$	$MgCl_2$*	$MgCl_2$	$MgCl_2$*
Na_2CO_3	Na_2CO_3	Na_2CO_3	$NaHCO_3$*	Na_2CO_3	Na_2CO_3	Na_2CO_3*	Na_2CO_3
$NaHCO_3$	Na_2SO_4	$NaHCO_3$	Na_2SO_4*	$NaHCO_3$	$NaHCO_3$	Na_2SO_4*	$NaHCO_3$
Na_2SO_4	$NaCl$	Na_2SO_4	$MgCl_2$	Na_2SO_4	Na_2SO_4	$NaCl$†	Na_2SO_4
$NaCl$	$NaHCO_3$	$NaCl$	$MgSO_4$	$NaCl$	$NaCl$	$NaHCO_3$†	$NaCl$

* Equally toxic. † Equally toxic.

A study of Table VII shows that, with the single exception of maize, the salts of magnesium are more toxic than those of sodium to all the plants tested.[a] This exception is the more remarkable since three other plants of the same family—wheat, oats, and sorghum—are included in the experiments. In most cases the sulphate of magnesium is more toxic than the chlorid. Sodium carbonate is from twice to four times as toxic to the white lupine, wheat, and maize as is the acid carbonate (bicarbonate), while to the other plants it is only slightly more toxic than the latter. Sodium sulphate, which is generally regarded as a less injurious component of "alkali" soils than sodium chlorid, in pure solutions is more toxic to nearly all the plants tested.

Returning to Table VI in order to compare the powers of resistance of the different plants, we find that maize is on the whole decidedly the most and cotton the least resistant of them all. Wheat stands next to maize among the more tolerant species, while the beet is on the whole the least resistant after cotton. How difficult it is to explain the behavior of plants in relation to saline soils as they occur in nature on the basis of such results as these with solutions of single salts, is shown by the fact that while the sugar beet is one of the plants best adapted to soils of that character, maize is generally regarded as very sensitive.

[a] To the Early Amber variety of sorghum, however, sodium carbonate is nearly or quite as toxic as the magnesium salts.

In tolerance of the two magnesium salts, maize heads the list and cotton comes last. To magnesium sulphate maize is from thirty-six to two hundred times as resistant as the lupine, five hundred times as resistant as the beet, and eight hundred times as resistant as cotton. Even among the four Gramineæ tested there is great difference in tolerance of this salt, maize being one hundred and thirty-three times as resistant as oats. Only less striking are the differences in tolerance of magnesium chlorid, maize, the species that is most resistant to this salt, enduring a concentration of solution two hundred times as great as that which is critical for cotton, the least resistant species.

Less striking results are brought out in the presence of the sodium salts, yet here also marked differences in tolerance occur. Maize endures three times as much sodium carbonate, ten times as much sodium sulphate, seven times as much sodium chlorid, and eight times as much sodium bicarbonate as does cotton.

It is evident from Tables III and IV and from Harter's results with wheat that different plants have widely different degrees of variability inside the limits of the species as regards resistance to salt solutions. Thus the Red Algerian oat is three times as resistant to magnesium sulphate as the Culbertson variety, and of the nine varieties of wheat with which Harter experimented some were three times as tolerant of magnesium chlorid and of sodium carbonate as were others.[a] Of four varieties of *Andropogon sorghum*, one, the Early Amber variety, endured five times as great a concentration of magnesium chlorid as that which was critical for the Dagdi Juar variety. Comparing two closely related species of the same genus, *Gossypium barbadense* and *G. hirsutum*, we find (Table II) that the former is twice as resistant as the latter to sodium carbonate.

RESULTS WITH MIXED SOLUTIONS.

As we have seen, the results of the experiments with solutions containing only a single salt can not be correlated with our knowledge of the relative resistance of the plants used when growing in natural "alkali" soils. Kearney and Cameron[b] pointed out that the clue to this discrepancy was to be found in the fact that in nature we have always to do with a mixture of salts and never with pure solutions. They found that by adding sodium salts to the solutions of magnesium salts the critical concentrations of the latter could be raised considerably and that the neutralizing effect in the case of *Lupinus albus* and *Medicago sativa* became enormous when salts of calcium were added to solutions of the sulphates and chlorids of magnesium and sodium.

[a] See Bul. 79, Bureau of Plant Industry, U. S. Dept. of Agriculture, pp. 25 and 27.
[b] See Report 71, U. S. Dept. of Agriculture, p. 27.

NEUTRALIZING EFFECT OF AN EXCESS OF CALCIUM SULPHATE.

Table VIII gives the critical concentrations of solutions for eight different plant species in the presence of an excess of calcium sulphate. In the case of *Lupinus albus*, *Medicago sativa*, and *Zea mays* these have been worked out with all six of the salts used in the experiments with pure solutions, while for the other species only the limits for magnesium chlorid, sodium carbonate, and sodium chlorid were ascertained.

TABLE VIII.—*Critical concentration for seedlings of various plants in mixed salt solutions (containing an excess of calcium sulphate), expressed in fractions of a normal solution.*

[The figures represent the critical concentrations for the more toxic salts, to which the calcium sulphate was added.]

Salts used (each mixed with an excess of calcium sulphate).	Plants used.*							
	Lupinus albus† (white lupine).	Medicago sativa (alfalfa).	Zea mays (maize).	Triticum vulgare (wheat).	Andropogon sorghum (sorghum).	Avena sativa (oats).	Gossypium barbadense (cotton).	Beta vulgaris (beets).
$MgSO_4$	0.4	0.35±	0.6	....	....	....	....	....
$MgCl_2$	.2	.2 ±	.3	0.225	0.2	0.175	0.25	0.2
Na_2CO_3	.03	.02	.05	.0275	.0225	.1025	.0275	.05
Na_2SO_4	.3	.3	.4 ±	....	....	....	....	....
NaCl	.2	.2	.25	.2	.15	.175	.2	.2
$NaHCO_3$	.05	.08	.1 ±	....	....	....	....	....

* The varieties are in all cases the same as those used in obtaining the corresponding limits in pure solutions (see Table VI, page 12).
† Using the fresh lot of seed which gave so much higher limits in pure solutions (see note to table, page 12), Harter repeated the experiments made by Kearney and Cameron with *Lupinus albus* in mixed solutions. In the presence of calcium sulphate, however, Harter's results agree closely with those obtained by Kearney and Cameron (given in Table VIII, column 2) the critical concentrations as determined by Harter being as follows: Magnesium sulphate, 0.35 normal; magnesium chlorid, 0.25 normal; sodium carbonate, 0.0375 normal; sodium sulphate, 0.25 normal; sodium chlorid, 0.175 normal; sodium bicarbonate, 0.058 normal.

In comparing the limits in mixed solutions as stated in the above table with those in pure solutions (Table VI, page 12), we notice that the order of toxicity of the different salts is considerably altered by the addition of calcium sulphate, sodium carbonate being in every case the one that becomes most toxic, while the critical concentrations of the sulphate and chlorid of magnesium become in all cases higher than those of the sodium salts except the sulphate. The neutralizing effect of calcium sulphate is therefore much more marked toward the magnesium than toward the sodium salts.

The presence of calcium sulphate tends very greatly to diminish not only the differences between different species as to their tolerance of the magnesium and sodium salts, but also the differences between the latter in their toxicity to the same species. The first effect is most strikingly illustrated by the limits for maize and white lupine in the presence of magnesium sulphate. The former will endure a concentration of this salt in pure solution from thirty-six to two hundred times as great as is tolerated by the latter. But when an excess of calcium sulphate is added the critical concentration for maize is less

than twice that for the white lupine. As an illustration of the tendency to equalization of the toxic effects of the different salts in the presence of calcium sulphate may be mentioned the fact that in pure solutions the sugar beet will endure fifty times as much of sodium chlorid as of magnesium chlorid, while the addition of calcium sulphate makes the critical concentration of both salts the same for this plant.

In some cases the relative resistance of two plants is reversed in the presence of calcium sulphate. Thus, sorghum is more resistant than cotton to pure solutions of magnesium chlorid and of sodium chlorid, but to the mixed solutions cotton is the more resistant. Oats are twice as sensitive as wheat to a pure solution of sodium carbonate, but to sodium carbonate plus calcium sulphate wheat is four times as sensitive as oats.

NEUTRALIZING EFFECT OF SMALLER AMOUNTS OF CALCIUM SULPHATE.

In all of the previously described experiments with mixed solutions, the solutions of magnesium and sodium salts were saturated with the neutralizing agent (calcium sulphate), which was added in excess as a solid.

It was therefore desirable to ascertain whether smaller amounts of calcium sulphate would not neutralize the toxic action of the various salts employed in pure solutions. Two series of experiments were carried out to determine this point, the first with *Lupinus albus*, the second with the Dagdi Juar variety of *Andropogon sorghum*. In the first series sodium chlorid was selected as the salt to be neutralized, while in the second results were obtained with sodium chlorid, sodium carbonate, and magnesium chlorid.

RESULTS WITH LUPINUS ALBUS.

Aqueous solutions of calcium sulphate of definite concentrations were added in equal volume to a solution of sodium chlorid, the concentration of the latter being varied until that was ascertained which represented the critical concentration for the root tips of the lupine seedlings in the presence of the amount of calcium sulphate that was added. A different method was followed in securing the maximum amount of calcium sulphate (3.69 grams per liter), an excess of calcium sulphate being in this case dissolved in various concentrations of the sodium chlorid solution itself,[a] and the latter being then tested until the critical concentration was ascertained. The limits for sodium chlorid in the presence of different amounts of calcium sulphate are stated both in grams per liter and in fractions of a normal solution of sodium chlorid present in the mixed solutions that were found to be critical.

[a] Calcium sulphate is of course much more soluble in a solution of sodium chlorid than in pure water.

TABLE IX.—*Critical concentrations for Lupinus albus in sodium chlorid plus different amounts of calcium sulphate.*

Amount of calcium sulphate present.		Critical concentrations of sodium chlorid.	
Degree of saturation.	Grams per liter in the mixed solution.	Grams per liter in the mixed solution.	Fractions of a normal solution.
Saturated in the NaCl solution	3.69	11.7	0.2
One-half saturated in H_2O	*1.062	12.3	.21
One-fourth saturated in H_2O	.531	12.5	.21
One-eighth saturated in H_2O	.265	10	.17
One-sixteenth saturated in H_2O	.132	7.5	.13
None	None.	1.17	.02

*Cameron (The solubility of gypsum in aqueous solutions of sodium chlorid, Journal Phys. Chem., 5:556, 1901) has shown that calcium sulphate dissolves in water at a temperature of 26° C. at the rate of about 1 part per 470 of water; hence at the rate of about 2.125 grams per liter. Marignac and Goldammer obtained similar results.

We see from these results that the maximum neutralizing effect of calcium sulphate upon sodium chlorid in raising the critical concentration of the latter for white lupine seedlings is reached when the mixed solution contains 0.5 gram of the calcium salt, and that the endurable concentration of sodium chlorid can be raised no further although the amount of calcium sulphate present be increased more than seven times. At concentrations below 0.5 gram per liter the effect of the calcium salt gradually diminishes. It would be interesting to ascertain the minimum amount of calcium sulphate that can perceptibly diminish the toxic effect of sodium chlorid.

RESULTS WITH ANDROPOGON SORGHUM.

In this series of experiments a saturated solution of calcium sulphate in water was prepared and was then diluted with distilled water to the desired concentrations. Normal solutions of sodium chlorid, sodium carbonate, and magnesium chlorid were obtained and then brought to the concentration that is critical in the presence of an excess of calcium sulphate by diluting with the different concentrations of the calcium sulphate solution that were used.[a] The object of this series of experiments was to ascertain the minimum amount of calcium sulphate which would have as complete neutralizing effect upon the more toxic salts as could be obtained by saturation with the calcium salt.

[a] Since the normal solutions contained no calcium sulphate it was necessary to correct for this in determining the amounts of calcium sulphate present in the total volume of the mixed solutions.

TABLE X.—*Minimum amounts of calcium sulphate giving the maximum neutralizing effect upon the toxicity of other salts to Andropogon sorghum.*

Salts neutralized.	Critical concentration when saturated with calcium sulphate.		Minimum amount of calcium sulphate giving neutralizing effect equivalent to that of saturation.	
	Fractions of a normal solution.	Grams per liter.	Fractions of saturation in the total volume of water in the mixed solution.	Grams per liter in the mixed solution.
Sodium chlorid	0.15	8.8	0.053	0.112
Sodium carbonate	.0225	1.2	.183	.389
Magnesium chlorid	.2	9.5	.3	.637

Comparing the results as to sodium chlorid given in Table X with those given in Table IX, we see that, while the concentration of that salt which is critical for *Lupinus albus* can be raised to 0.2 normal by the addition of calcium sulphate, for *Andropogon sorghum* the limit can be raised to only 0.15 normal. On the other hand, the minimum amount of calcium sulphate required to produce the maximum neutralizing effect is only about one-fifth as great for the latter plant as for the former. Table X also shows that the maximum neutralizing effect is obtained by widely different amounts of calcium sulphate in the case of each of the three more toxic salts, and that the more toxic the salt in pure solution the greater is the amount of calcium sulphate required to produce the maximum possible neutralizing effect.

If we compare the limits of this variety of *Andropogon sorghum* in pure solutions, as stated in column 5 of Table III (p. 10), with those in mixed solutions, as given in Table X, we observe that the critical concentration of magnesium chlorid can be raised one hundred and sixty times by the addition of calcium sulphate, while that of sodium carbonate can be raised only three and six-tenths times. Yet to obtain the former result less than twice as much calcium sulphate is required as to obtain the latter.

To neutralize sodium carbonate as completely as possible, three and one-half times as much calcium sulphate is required as in the case of sodium chlorid, although the fraction of a normal solution representing the critical concentration of the mixed solution is only one-seventh as great for the former salt as for the latter. Six times as much calcium sulphate is needed to produce the greatest possible neutralizing effect upon magnesium chlorid as upon sodium chlorid, yet the critical concentration of the former in the mixed solution is only slightly greater than that of the latter.

That there is no close quantitative relation between the amount of the more toxic salt present in the mixed solution and that of calcium sulphate necessary to neutralize it is evident from the fact that, in

weight of salt per liter of solution, the minimum amount of calcium sulphate necessary to effect the maximum possible neutralization, as compared with the amount of the more toxic salt present in the mixed solution, is about one-third in the case of sodium carbonate, one-fifteenth in that of magnesium chlorid, and one-eightieth in that of sodium chlorid. This is a strong indication that the neutralizing effect is a physiological one, and that it can probably be satisfactorily explained only when the composition and properties of living protoplasm are better understood.

Prof. O. Loew and his students, in numerous papers dealing with the "lime-magnesia ratio," have thrown much light upon the effect of calcium salts in neutralizing the poisonous action of salts of magnesium. The physiology of the decrease in toxicity of salts of sodium and magnesium brought about by the presence of a second salt, especially a salt of calcium, in the solution, was discussed by Kearney and Cameron[a] in connection with Loeb's striking results with marine animals. Osterhout[b] has recently investigated this subject from the point of view of Loeb's conception of a "physiologically balanced solution" and has shown that marine plants as well as marine animals are very sensitive to pure salt solutions, but thrive in solutions containing a mixture of salts, even when each component is present in an amount that is toxic in pure solution. A mixture of the more important salts present in sea water, each at about the concentration at which it occurs in the sea, was found to be the best medium for the growth of marine algæ.

> The plants die much sooner in a pure sodium chlorid solution (isotonic with sea water) than in distilled water. The poisonous effect of the NaCl largely disappears if we add a little $CaCl_2$. * * * In this mixture the plants live nearly as long as in distilled water. Addition of KCl to this mixture enables them to live longer than in distilled water. Further addition of $MgCl_2$ and $MgSO_4$ enables them to live practically as long as in sea water.[c]

SUMMARY.

(1) Different varieties of the same species, e. g., of wheat (*Triticum vulgare*), sorghum (*Andropogon sorghum*), and oats (*Avena sativa*), differ considerably in their powers of resistance to the action of magnesium and sodium salts in pure solutions.

(2) Closely related species of the same genus, e. g., Egyptian and Upland cottons (*Gossypium barbadense* and *G. hirsutum*), show similar differences.

(3) Great differences exist between different plant species, even when belonging to the same family, in tolerance of pure salt solutions,

[a] Report No. 71, U. S. Dept. of Agriculture, 1902, pp. 40 to 47.
[b] Jour. Biol. Chem., 1:363 to 369, 1906, and Bot. Gaz., 42:127 to 134, 1906.
[c] Osterhout in Bot. Gaz., 42: 130 (1906).

not only as regards the absolute toxicity of each salt but also as regards the relative order of toxicity of the salts. Of the eight species used in these experiments maize (*Zea mays*) is, on the whole, the most resistant to pure solutions, and cotton (Gossypium) the least.

(4) Seedlings grown from fresh seed are much more resistant than those developed from older seed.

(5) The presence of calcium sulphate in excess greatly diminishes the toxicity of the magnesium and sodium salts to all the plants tested, the neutralizing effect being greatest in the case of the sulphate of magnesium and least in that of sodium carbonate.

(6) The addition of calcium sulphate tends to equalize the toxicity of the different magnesium and sodium salts.

(7) As a rule, the more sensitive the species to the pure solution the greater is the counteracting effect of the calcium salt; hence, the presence of the latter tends to diminish the differences in resistance shown by different plant species in the presence of pure solutions.

(8) Amounts of calcium sulphate smaller than that necessary to saturate the mixed solution also show a marked neutralizing effect upon the more toxic salt, but the minimum amount of calcium sulphate capable of producing such effect remains to be determined.

(9) For the white lupine the presence of 0.5 gram of calcium sulphate is as effective as seven times that amount in neutralizing sodium chlorid, while for sorghum 0.1 gram is as effective as twenty times that amount.

(10) To secure the most effective possible neutralization of sodium chlorid five times as much calcium sulphate is required in the case of the white lupine as in that of sorghum, although the limits for these two plants are approximately the same both in pure sodium chlorid and in sodium chlorid plus an excess of calcium sulphate.

(11) While the comparative resistance of the different plants to pure solutions of the single salts can in no way be correlated with that of the same species to the different combinations of "alkali" salts occurring in western soils, their behavior in mixed solutions shows a much closer approach to that observed under natural conditions.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 114.

B. T. GALLOWAY, *Chief of Bureau.*

SAP-ROT AND OTHER DISEASES OF THE RED GUM.

BY

HERMANN VON SCHRENK,

FORMERLY EXPERT IN CHARGE OF MISSISSIPPI VALLEY LABORATORY.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 24, 1907.

Sir: I have the honor to transmit herewith a paper entitled "Sap-Rot and Other Diseases of the Red Gum," by Dr. Hermann von Schrenk, formerly expert in charge of the Mississippi Valley Laboratory of this Bureau, and recommend that it be published as Bulletin No. 114 of the series of this Bureau.

Acknowledgment is made of our indebtedness to the Chas. W. Luehrmann Hardwood Lumber Company and to the Indiana and Arkansas Lumber Company, both of whom rendered special assistance in carrying on the work.

The accompanying illustrations are essential to a clear understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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SAP-ROT AND OTHER DISEASES OF THE RED GUM.

INTRODUCTION.

The red gum (*Liquidambar styraciflua*) is a tree which is singularly free from fungous diseases when compared with other species of hardwood trees. This comparative freedom from disease it shares with many other species of more or less ancient geologic lineage.[a]

One of the reasons why the trees are so immune to the attacks of fungi may be sought for in the production of a kind of gum or resin which is present in almost all parts of the trees. The resin appears as a yellowish-brown, semitransparent liquid, with a very bitter taste, in wounds and on the bud scales of our American species. It is commercially known as liquidambar or copal balm. *Liquidambar formosana* produces a similar terebinthinous resin and *L. orientalis* has a similar substance from which the storax, another resin largely used in China, is obtained.

The principal reason for the comparative immunity from disease is probably the fact that in the course of its development from the

[a] The species of Liquidambar date from the Tertiary epoch, during which period one species (*L. californicum*) flourished on the western slopes of the Sierra Nevada in California. "The immediate ancestor of the interesting American species inhabited Alaska, Greenland, and the midcontinental plateau of North America, and later was widely distributed in the Miocene of Europe, where have been found the traces of a second species similar in the form of its leaves to the present representative of the genus in western Asia." (Sargent, C. S., Silva of North America, 5:7; 1903.)

Lesquereux reports the same species from the Miocene from Alaska and the Chalk Bluffs of California.

Lesquereux (The Cretaceous and Tertiary Floras; Rep. U. S. Geol. Survey, 8:159; 1883) reports *L. europaeum* Al. Br. from Wyoming. *L. europaeum* was very common in the Miocene of Europe. Lesquereux also describes *L. integrifolium* Lesqu. from Salina, Kans. (The Cretaceous Flora; Rep. U. S. Geol. Survey, 6:57; 1874.)

At the present time only three species of Liquidambar are known, viz, *L. styraciflua* from the United States, *L. orientalis*, from southwestern Asia Minor, and *L. formosana*, from China and Formosa.

early Tertiary period up to the present time a gradual elimination of those individuals which tended toward becoming diseased has taken place. In other words, the genus has been tending more and more toward becoming immune, because of the survival of such individuals as showed greater immunity to infection by fungi which tend to shorten the life of the trees. The present comparative freedom from serious disease is therefore probably to be explained by a simple process of natural selection, which has produced a race of almost immune individuals. This evolution against disease is one which the red gum shares with many other species of ancient lineage, such as the bald cypress, the redwood, and the sycamore.

The heartwood of the red gum is comparatively long lived when exposed to weathering influences. It has been used for a great many years in the construction of buildings, where it has served for foundation timbers, and in some instances in bridge construction. When thoroughly dried before being exposed, its length of life is comparatively great. Some instances are known to the writer where timbers of heart red gum have served as foundations in sawmills in Arkansas for fifteen years or more. Railroad ties have been made of red gum in the Mississippi Valley for a good many years and have shown a lasting power of from seven to eight years or longer. (Pl. VII, fig. 2.) Even the sapwood, which, as will be seen, is very rapidly destroyed by fungi when in a green condition, can be made to last a long time. See Plate VII, fig. 1, representing a section of a cross-arm, one of many made of red gum which had been in service on an electric-light line in eastern Arkansas for eight years. The country in which these cross-arms were exposed has probably as humid and hot a climate as can be found. In spite of this, the timber shows practically no change after eight years' exposure.

While the live tree shows few diseases, the cut timber, unless properly handled, is very liable to decay. During recent years, with the increased quantity of gum timber cut, a number of serious diseases have caused losses of a severe character every year. In the following pages are described some of the diseases of the living tree and a sap-rot of the structural wood, with suggestions as to methods for preventing the latter.

DISEASES OF THE LIVING TREE.

As has been stated, the living trees of the red gum are generally free from very serious fungous diseases. Those diseases that are present usually manifest themselves in the form of butt-rots. There are no very serious diseases of the tops of the trees nor of the leaves or branches. Of the butt-rots there are several forms which are found almost wholly in older trees. Old trees when cut down will,

in a large majority of cases, be found to have hollow butts. The hollow extends up into the trunk from 2 to 15 or 20 feet. When cut down the interior of the hollow will be filled with a more or less powdery mass of decayed wood, a condition brought about by the joint action of various boring insects and saprophytic fungi. The inner portions of the trunk are generally so thoroughly decayed that it is impossible to recognize any one particular form responsible for the destruction. On the border between the sound wood and the decayed portion a number of definite forms of decay have been noted, several of which are described below.

YELLOW BUTT-ROT.

One of the commonest appearances in the butts of the gum is a form of decay which renders the wood more or less cheese-like in character and turns the heartwood from red to a yellowish brown. The wood is thoroughly permeated by fine strands of white fungous mycelium, which extend both longitudinally and radially throughout the wood. (See Pl. I, fig. 1.) In advanced stages the wood is soft and pulpy and can readily be crumbled into a powdery mass. This form of rot is the most common one in the butts of the trees, and in several instances was found extending up 15 to 20 feet into the tree. In one trunk a fruiting organ was developing in the hollow. The same is a form of Poria. The spores are very short and snow white in color. The hymenium adapts itself to the irregularities of the decaying wood.

A form of decay is produced by *Polyporus lucidus*. The decay resembles that just described and may, in fact, be the same. In the case of one particular stump large sheets of white mycelium formed between various annual rings, and the wood appears very much firmer than that in the yellow butt-rot described above. The fruiting organ of this fungus in one case developed in about two months from the time the trees were cut down. The top surface of the sporophore appears highly varnished, with numerous definitely marked concentric layers. The lower surface is more or less cream-colored to white. When wounded the lower surface turns blood red.

SPECKLED ROT.

A second form of decay which appears very commonly in the hollow butts of trees changes the wood into a porous mass consisting of a large number of small cavities bounded by layers of sound wood. It resembles very much the decay produced in oak by various species of Stereum. This form of decay, while common in the butt, may occur far up into the tree. The tree from which the piece shown in Plate I, figure 2, was taken was decayed entirely into the center, as a result

of which condition the tree had been broken off by the wind at a point about 12 feet from the ground. This form of decay is very distinct from the one just described and will always be known by the peculiar circumscribed holes formed throughout the mass of the wood fibers. Only one fungus has been associated with this form of decay, and it is rather doubtful whether this fungus, a Poria, is responsible for it.

PIPED ROT.

A third form of disease is found in the center of living gum trees. The summer wood appears to be changed into cellulose in regular layers. The wood as a whole has a very bright yellow-brown appearance, evidently due to the mycelium of the particular fungus causing the decay. Only one tree answering this description was found. From its appearance, the disease seemed to extend about seven or eight feet up into the trunk.

LEAF DISEASES.

About eighty species of fungi growing on the leaves and branches of the red gum have been described. Most of these are very inconspicuous, however, and do not cause any very serious damage to the trees. Among them may be mentioned *Valsa liquidambaris* Curtis, *Seiridium liquidambaris* B. & C., and *Septoria liquidambaris* Cook & Ellis.

SAP-ROT.

After the trees of the red gum are cut into logs a number of destructive fungi attack the sapwood with such rapidity that after a very few months the wood is rendered wholly worthless. The red gum shares this susceptibility to rapid decay of its sapwood with many other hardwood and coniferous trees. Of these may be mentioned in particular the tupelo gum, beech, maple, swamp oaks, and loblolly pine. There is a large group of fungi which thrive upon the sapwood of trees after they have fallen and bring about a kind of decay, which may for convenience be called sap-rot. The sap-rot of the gum forms one of the worst defects of this valuable wood and has resulted in very serious commercial losses during late years.

OCCURRENCE OF THE DISEASE.

In many regions where the red gum is cut for its lumber the logs are sawed in the woods and are then skidded either to the railroad or, more frequently, to the bank of some river. Where logs are taken to the mill by means of a railroad and sawed at once the sap-rot usually does not give much trouble. The boards dry out in the piles to such an extent that the growth of the fungus is made impossible. Where logs are rafted, however, the sap-rot will start in the logs,

depending upon the season of the year, from one to several weeks after the logs are cut. When green the red gum has such a large quantity of water in its trunk that it will sink when put into water, and it is therefore impossible to raft green red gum, even with the assistance of lighter species of wood. For this reason the logs are usually piled along the banks of streams for five or six months, or longer, until they have dried out to such an extent that they can be rafted by the aid of cottonwood or other lighter logs. In almost all cases the trees are simply cut down and sawed into the standard lengths (12, 14, and 16 feet). The bark is left on the logs. When skidded along the bank of the river the logs are usually placed in irregular close piles, most of the logs lying directly on the ground.

The sap-rot makes its principal appearance during the months from May to October, and in the extreme Southern States, where the summer temperatures are very extreme, and particularly in the more or less swampy countries where the red gum grows, the development of sap-rot takes place with great rapidity. Logs which are left on the banks of southern streams and examined during the months of July, August, and September will appear blackened on the ends; molds and toadstools of all kinds will be found growing on the ends, while the sap which has exuded will look dark and generally has a sour, more or less acid, odor. The evidences of fermentation due to yeasts and molds of various kinds have given the cut surfaces of the sapwood a black, stained appearance. (See Pl. II, figs. 1 and 2.) Not infrequently the small sawdust piles of a species of bark-boring beetle are more or less evident. Where the sawed ends are pointed so that the sun shines upon them during a large part of the day the logs may not show any evidences of fungi or toadstools, but in almost all cases the sapwood will look stained, and usually black, because of a surface mold. While it is generally realized by lumbermen that the summer months produce an inferior grade of lumber, it has nevertheless not been found possible to restrict the cutting of logs to the winter period. The investment in camps, teams, etc., and the difficulty of obtaining labor unless constantly employed have necessitated operations extending through the entire year. On that account, although the losses due to cutting the timber during the summer months have in many instances been very great, the cutting operations have not been restricted.

When the logs have dried out sufficiently on the banks, they are made into rafts and are towed or floated to the sawmill. This takes place usually during December and January when a sufficient amount of water can be obtained. On arriving at the sawmill it will be found that the summer-cut logs manufactured into boards show a decay which has extended in from both ends of the log

throughout the sapwood for distances varying from several inches to several feet. When it is remembered that the logs are 12, 14, and 16 feet long, and supposing that a log is decayed in from both ends for a distance of 2 feet or more, making 4 feet or more for one log, it will readily be seen that the amount of loss incurred because of this end rot is very considerable.

DESCRIPTION OF SAP-ROT IN BOARDS.

The decayed boards present a very striking appearance. The normal color of the sapwood of the gum is a light straw-yellow, verging in many cases into a color which may be called a light brown. The decayed board is characterized by a series of various-colored streaks or lines distributed in an irregular manner from the end of the log toward the middle. These streaks (shown in Pl. III) are light orange in the region of first change—the region bordering upon the sound wood. When the wood has decayed further, this color changes to a very light straw-color, which is almost white. Mixed in with this white color are distinct lines and patches having a bluish tinge, more properly described as Payne's gray. Here and there sound pieces of the brownish-colored normal wood will appear, and where the decay has proceeded to a considerable extent black zigzag lines, such as are found in many hardwoods, extend from the end parallel to the wood fiber for 2 or more inches into the board. A partially decayed board appears as if irregularly bleached; that is, it looks as if the action of the fungus had destroyed the natural color of the wood fiber, leaving certain decomposition products in the wood which give it the yellow-brown and bluish color. The decay is one of the most striking which have been found in either hard or soft woods and one which it will be almost impossible to mistake when once seen.

The general consistency of the wood is firm and solid; in other words, the preliminary changes resulting in the color changes referred to, while they appear very striking, do not seem to involve any material disintegration of the wood fiber. It is only after the fungus has grown for a considerable distance into the wood—for 2 or 3 feet—that a marked disintegration results. The wood then becomes more or less pulpy and soft and loses its firm character. If left long enough the entire board may become affected, and where logs have been left on the banks of streams or in the woods for a year or more the entire sapwood will become so thoroughly permeated by the mycelium of the fungus that it is practically entirely destroyed.

MICROSCOPIC CHANGES IN DECAYED WOOD.

The microscopic changes in red gum wood due to various forms of sap-rot consist principally in a destruction of the red coloring matter of the wood cells. The affected masses of wood appear bleached, as if the fungus had dissolved the color. After the fungus has grown in the wood for some time, a gradual solution of the cell walls becomes evident. Large masses of brown and colorless fungous threads fill the cell lumen. The details of the changes brought about in the fiber are of minor importance in this connection, and a description will be found elsewhere.

THE FUNGUS WHICH CAUSES SAP-ROT.

Freshly sawed boards which show the discoloration just referred to, when piled in the yard to season, generally contain sufficient water to permit the fungus within the wood fibers to continue its development. It is no unusual sight in piles which contain the partially decayed boards to find the fungus flourishing on the surface of the boards, generally most profusely on the lower side, where the sun can not get at the surface and where there is therefore more or less moisture. After several weeks the threads of the fungus will grow out from the white portions of such boards, and after several additional weeks the fruiting bodies of the fungus will form in long lines on one or both surfaces. (See Pl. IV, fig. 2.) These fruiting bodies will likewise form in considerable number on the ends of affected boards, and in going through a yard there will be found a large number of such boards with the shelf-like fruiting bodies in various stages growing out from the ends. (See Pl. IV, figs. 1 and 3.) In making an examination of the fruiting bodies one will find that there are a number of fungi which apparently flourish in the sap-wood of the red gum and bring about the changes referred to above. The most frequent one is a widely distributed form (*Polyporus adustus*). (Pl. IV, figs. 1 and 2.) This fungus appears in the form of small shelves, either singly or in groups, depending upon whether they form on the side or the end of the planks. Where a plank is lying horizontally the fungus may appear in the form of extended sheets, one margin of which will be slightly turned at an angle of 90° to the surface of the board, forming a partial pileus. (Pl. IV, fig. 2.) Where a large amount of moisture is available in the boards or timbers the fungus may form large sheets from which horizontal shelves will project which bear the hymenial layer. The shelves of this fungus vary in size from the smallest specks (see Pl. IV, figs. 1, 2, and 3) to extensive bodies 2 inches in width. The average size, however, is about a half inch in width and about the same in depth.

The normal fruiting bodies are pale yellow in color on the top and a dusky brown on the lower side of the shelves. The young fruiting bodies are almost orange in color. The top surface in the young fruiting body is very soft and woolly. As the fruiting body becomes older this woolliness becomes more distinct, and in the older forms the top may be entirely woolly. There are, on the other hand, numerous forms which are almost smooth. Where the fungus develops on the underside of trunks in the forest or between boards lying one on the other it appears usually in the form of extended sheets, the pores of which point both up and down, depending upon the position of the board. When growing in the forest on old logs the masses of this fungus may be found covering the entire sapwood for areas of several square feet, in which several hundred shelves will be found, all coming from a flattened sheet of tissue. Many of the fruiting bodies will be united more or less, but most of them are perfectly free at the edges. (Pl. II, fig. 2.)

In freshly sawed boards it is not unusual to find more than 75 per cent of the boards in one pile forming the fruiting bodies within two weeks after the boards are piled in the stack. The outside of the board may appear perfectly good, particularly when inspected on the end, and the only evidence that one has to deal with a defective stick will be found in the large number of small shelves which appear on the ends of such boards. The rapidity with which the fruiting organs will form on the board will perhaps be best shown by an experiment made during the past summer. A board, the end of which was covered with thirty or more distinct fruiting bodies, was sawed across at a point 1 inch in from the end, leaving a perfectly smooth surface. Three weeks later this same board was again covered by some thirty or forty fruiting bodies fully formed and mature. This happened during the month of August, 1905.

POLYPORUS ADUSTUS.

Boletus adustus Willd. Fr.[a] (Flora Berol., p. 392, 1787).
Polyporus adustus (Willd.) Fries (Syst. Myc., 1: 363; 1821).

The fungus which causes the sap-rot of the red gum has been found on almost all deciduous woods. So far as known, it does not grow on coniferous woods. It has been reported as growing on the wood of maple, alder, birch, ironwood, chestnut, beech, ash, hickory, walnut, red gum, mulberry, magnolia, sycamore, poplar, oak, locust, willow, tulip, and elm. It probably grows on fallen wood of other hardwood trees.

[a] Only a partial citation of the synonymy of the various fungi growing on gum is made in this bulletin. The full discussion of this subject will be found elsewhere.

Polyporus adustus has been found practically all over the world in the temperate zones. It is one of those fungi which are not adapted to any particular species of wood, but flourish in almost all hardwoods of the temperate zones. It is known to occur in Patagonia and the Argentine Republic in South America. In Europe it has been found in Switzerland, England, Norway, France, Holland, Finland, Denmark, and Russia. In Australia it is reported from New South Wales and Queensland. In North America it grows in Cuba, Canada, and the United States. In the United States it has been found in most of the States east of the one hundredth meridian. West of that line, possibly owing to the prevalence of coniferous forests, it is not reported.

In the forests of the southern United States *Polyporus adustus* is one of the commonest of forms. In the regions where the investigations herein outlined were conducted fruiting bodies of this fungus were common on many tops and branches of the red gum. They were particularly prevalent on tops and branches of trees which had been sawed during the months of April, May, and June. An examination made in this region in October showed that on a large number of the tops sawed several months previously enormous masses of the fruiting bodies of *Polyporus adustus* abounded. (See Pl. II, fig. 2.) It is therefore not surprising that freshly cut trees should become affected with the spores of this fungus within a few days or weeks after the trees are felled. At the period when the logs are felled they are full of water and contain an abundance of organic matter, thereby offering the very best field for the germination and early development of the wood-destroying fungus. The large amount of sugar and other organic compounds present is well evidenced by the prolific development of molds and yeasts on the ends of freshly sawed logs already referred to.

PREVENTIVE MEASURES AGAINST SAP-ROT.

PREVENTION IN THE PILE.

After the fungus has once entered a log it is practically impossible to get rid of it. When infected logs are brought into the sawmill and boards are manufactured therefrom growth will continue in the piles, as already mentioned, unless elaborate precautions are taken to so pile the boards that they will lose their water so rapidly that development is made impossible for the fungus. Various methods have been tried from time to time by lumber companies to prevent the growth of this fungus. A notable one consisted in the application to the ends of affected boards of a thick solution of lime, the idea being that it might thereby be possible to kill the so-called mold within the board.

In a majority of instances applications of this character resulted not only in absolute failure, but hastened the growth of the fungus by preventing the evaporation of water from the ends of the boards. Applications of any chemicals, such as lime, to the outside of boards can not be too strictly condemned.

The only possible way in which the growth of the fungus after it once is in the boards can be stopped is, as already stated, to reduce the quantity of water in the board. In order to accomplish this the boards should be piled in the most open piles which it is possible to construct economically; the spaces between layers should be made at least 1½ to 2 inches. The crossing strips employed should preferably be of some wood other than red gum, possibly oak, and carefully seasoned before being used. The use of crossing strips of red gum brings about a condition in the surfaces which touch one another leading to infection of the crossing strips, which, if used again, may infect boards which up to that time may have been free from the decay-producing fungus. Individual piles should be constructed so as to permit the greatest possible air circulation. At least 8 feet should be left between the piles, and preferably more. Obstructions which would be likely to impede the circulation of the air, such as the use of flat boards for the bracing of runways, should be discouraged. It was found, for example, that in one yard the lower half of the piles, or, more properly stated, that part of the pile below the runway, showed a very much higher percentage of badly decayed boards (boards which had deteriorated over 50 per cent after piling) than did the part of the same pile situated above the runway. In laying out yards care should be taken to so construct them that the prevailing winds blow down the main streets of the yard; in other words, that the direction of the wind shall be across the ends of the boards, i. e., at right angles to the length of the board. Where the wind is allowed to blow in the direction of the length of the board free air circulation is impossible, as the air circulation is constantly impeded by the crossing strips and by succeding series of piles.

A marked improvement in respect to the rate of development of this and other wood rotting and staining fungi was noted in one yard in which a complete change in the methods of piling, in line with the suggestions just made, was effected. Where crossing strips are to be used again and again it may pay in many instances to treat these chemically with mercuric chlorid. For this purpose a vat made entirely of wood is constructed. No iron should enter into the construction of the vat, as iron is likely to precipitate the mercury from solution. Crossing strips should be piled in this vat and clamped down so that when the solution is run in they may remain submerged. A solution of mercuric chlorid (corrosive sublimate), 1 part of sublimate to 150 parts of water, is then run in and the crossing strips are

allowed to remain in this solution for a period of from seven to ten days. They are then removed and allowed to dry. This treatment will cost about 4½ cents per cubic foot of wood. Crossing strips treated in this manner will practically last an indefinite period of time, and there will be absolutely no opportunity for communicating the infection from board to board.

TESTS MADE FOR PREVENTING SAP-ROT IN LOGS.

In view of the fact that the spores of the rot fungus (*Polyporus adustus*) apparently germinate on the ends of freshly cut logs, it was thought that the application of fungicides of one kind or another to the ends of freshly cut logs might retard the germination of these spores or possibly prevent their germination altogether.

PRELIMINARY TESTS.

In order to test the theory just mentioned a number of living trees were cut near Marianna, Ark., on June 1, 1905, and were sawed into logs 12 feet in length. These 12-foot logs were in turn cut in half, giving two 6-foot logs—a butt and a top piece. The top and butt pieces of each 12-foot log were kept together. One half received treatment and the other half was left untreated. In the following table the 12-foot logs numbered in a series are shown in the first column. The second and third columns give the numbers which were assigned to the 6-foot pieces in the experiment, and show in each case whether it was a top (T) or butt (B).

TABLE I.—*Weights of treated and untreated red gum logs, showing loss of moisture.*

CRUDE PETROLEUM.

No. of log.	Untreated.	Treated.	Original weight, June 2, 1905.	Weight Aug. 7, 1905.	Loss in pounds.	Percentage of loss.	Weight Jan. 15, 1906.	Loss in pounds.	Percentage of loss.
1	10752 T....	....	375	318	57	15.2	295	80	21.3
1	....	10753 B....	440	384	56	12.7	362	78	17.7
2	10754 B....	....	464	405	59	12.7	378	86	18.5
2	....	10755 T....	411	360	51	12.2	338	73	17.7
3	10756 T....	....	480	419	61	12.7	397	83	17.3
3	....	10757 B....	519	444	75	14.4	412	107	20.6
4	10758 B....	....	535	452	83	15.5	418	117	21.9
4	....	10759 T....	410	357	53	12.9	338	72	17.5
5	10760 T....	....	521	441	80	15.3	422	99	19.0
5	....	10761 B....	608	523	85	13.9	490	118	19.4
6	10762 B....	....	809	661	148	18.3	610	199	24.6
6	....	10763 T....	648	542	106	16.4	496	152	23.4
7	10764 B....	....	426	359	67	15.7	330	96	22.5
7	....	10765 T....	448	404	44	9.8	378	70	15.6
8	10780 B....	....	820	694	126	15.4	644	176	21.4
8	....	10781 T....	651	568	83	12.7	530	121	18.6
9	10782 B....	....	518	446	72	13.9	402	116	22.4
9	....	10783 T....	485	417	68	14.0	386	99	20.4
10	10784 B....	....	645	565	80	12.4	521	124	19.2
10	....	10785 T....	530	460	70	13.2	428	102	19.2
11	10788 T....	....	682	567	115	16.9	538	144	21.1
11	....	10789 B....	850	722	128	15.0	668	182	21.4
12	10790 B....	....	548	467	81	14.8	442	106	19.3
12	....	10791 T....	495	436	59	11.9	415	80	16.1

TABLE I.—*Weights of treated and untreated red gum logs, showing loss of moisture*—Continued.

CREOSOTE.

No. of log.	Untreated.	Treated.	Original weight June 2, 1905.	Weight Aug. 7, 1905.	Loss in pounds.	Percentage of loss.	Weight Jan. 15, 1906.	Loss in pounds.	Percentage of loss.
1	10766 B....	....	518	427	91	17.6	404	114	22.0
1	....	10767 T....	559	455	104	18.6	460	99	17.7
2	10768 T....	....	471	405	66	14.0	384	87	18.4
2	....	10769 B....	460	399	61	13.2	370	90	19.5
3	10770 B....	....	521	436	85	16.3	403	118	22.6
3	....	10771 T....	472	405	67	14.2	368	104	22.0
4	10772 B....	....	779	671	108	13.9	642	137	17.5
4	....	10773 T....	663	571	92	13.9	520	143	21.5
5	10774 B....	....	866	731	135	15.6	692	174	20.1
5	....	10775 T....	938	820	118	12.6	778	160	17.0
6	10776 T....	....	1,000	849	151	15.1	790	210	21.0
6	....	10777 B....	998	840	158	15.8	764	234	23.4
7	10778 B....	....	655	555	100	15.3	510	145	22.1
7	....	10779 T....	573	502	71	12.4	468	105	18.3
8	10787 B....	....	920	752	168	18.3	698	222	24.1
8	....	10788 T....	740	632	108	14.6	562	178	24.0
9	10792 B....	....	465	404	61	13.1	374	91	19.5
9	....	10793 T....	430	357	73	17.0	326	104	24.1
10	10794 B....	....	660	558	102	15.5	527	133	20.1
10	....	10795 T....	690	606	84	12.2	565	125	18.1
11	10796 T....	....	705	600	105	14.9	551	154	21.8
11	....	10797 B....	645	548	97	15.0	505	140	21.7
12	10799 B....	....	630	538	92	14.6	498	132	20.9
12	....	10800 T....	525	464	61	11.6	428	97	18.4

Two treatments were used. One set of logs was treated with crude Pennsylvania petroleum and another set was treated with ordinary coal-tar creosote. In each case one half of each 12-foot log was treated with either petroleum or creosote and the other half left untreated.

The treatment was carried out as follows: The petroleum or creosote was heated in a kettle to about 150° F. The liquid was then applied to the ends of the logs with a whitewash brush. Several applications were made in each instance, the second application following the first as soon as the creosote or petroleum had soaked into the log. The logs absorbed both the creosote and petroleum very readily, the petroleum more so than the creosote. The amount of creosote or petroleum used was approximately about 1 pound for each log. Both ends of these 6-foot logs were treated.

The only objection which could be advanced against the end treatment is that the application of the preservative might so retard the evaporation of the water from the ends of the logs that a condition would arise in the wood immediately inside of the treated layer most favorable for the development of the fungous spores, should these have found entrance through the treated layers. The chances for such entrances are decidedly good ones, because the gum logs begin to check very soon after they start to dry.

Several years ago a test was made with loblolly pine cross-ties treated with zinc chlorid and then with creosote to determine whether the water injected into the wood with the zinc chlorid would evapo-

rate through the creosote, and, if so, how rapidly this would take place. The following summarized table shows the results obtained, a thousand cross-ties being used for the test:

TABLE II.—*Weight of railroad cross-ties of loblolly pine at various periods after treatment with zinc chlorid, followed by creosote, showing the rate of evaporation of water.*

Dry weight before treatment.	Weight immediately after treatment.	Weight 5 days after treatment.	Weight 10 days after treatment.	Weight 16 days after treatment.	Weight 30 days after treatment.	Weight 60 days after treatment.	Weight 90 days after treat ment.	Weight 123 days after treatment.	Weight 1 year after treatment.
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
152.4	213.3	198.8	186.9	172.3	168.8	151.4	144.4	138.9	131.7

It appears from this table that the water evaporated through the surrounding creosote layer, and apparently with great rapidity, because sixty days after treatment the ties had lost all of the water injected and weighed as much as they did before the treatment. With these results in mind, it seemed probable that the end treatment of the green gum logs would probably not retard the drying of these logs very materially.

In order to determine, however, whether the application of the petroleum or creosote in any way retarded the rate of evaporation of water from the perfectly green log, all the 6-foot logs were weighed before the treatment. The logs were weighed again August 7, 1905, and for a third time January 15, 1906. The rate of loss of the untreated log and its companion treated log, both coming from the same tree, is shown in Table I.

It will be noted that in some cases the treated log lost more than the untreated log; in other cases the reverse was true. The average loss shows that the treated logs dried out with almost the same rapidity as the untreated ones. This goes to show that the application of a thin layer of petroleum or creosote to the end of the log practically does not retard the evaporation of water, and consequently the chances of fungous infection inside of the treated layer will not be greater in the treated logs than in those that are not treated.

SECOND SERIES OF TESTS.

A second series of tests was made in the forest near Levesque, Ark., on August 1, 1905. A series of freshly cut gum logs was selected on the skidway and provided with numbers. In one series the ends of all the logs were painted with creosote. Another set of logs on a subsequent date was painted entirely with petroleum. A third series was untreated. In the fourth series only the sap portion of the end was treated with petroleum, and the fifth series of experiments con-

sisted of painting only the sapwood with creosote. The bark was left on the logs in all cases, and after the treatment the logs were left on the ground near the river, pointing north and south. (Pl. V, fig. 1.)

The following table shows the number of logs treated and the manner of treatment:

TABLE III.—*Number of red gum logs receiving various treatments, August 1–5, 1905.*

	Logs.
Creosoted all over, Nos. 23525 to 23552	28
Creosoted, sapwood only, Nos. 23553 to 23558	6
Oiled all over, Nos. 23559 to 23573	15
Oiled, sapwood only, Nos. 23574 to 23591	18
Creosoted, sapwood only, Nos. 23592 to 23602	11
Oiled, sapwood only, Nos. 235603 to 235621	19
Untreated, Nos. 23501 to 23524	24

THIRD SERIES OF TESTS.

Believing that no risk would be involved in the treatment on a large scale of freshly sawed logs, the lumber company was advised to treat all of its logs during the past summer with creosote or petroleum. At Levesque, Ark., this treatment was carried out with every log from August to October. It was argued that untreated logs would certainly decay as rapidly as they did during the preceding season; and as the preliminary indications as to loss of water by treated logs showed that the treatment did not retard drying, the treatment could certainly do no more damage than the fungus, and it might do considerable good. On this account all of the logs cut at that point were treated with creosote or with petroleum. All of these logs were piled with those treated in the second series. The number of logs so treated was 1,769, having 605,809 feet B. M., of which half were treated with creosote and the other half with petroleum.

COST OF TREATMENT.

The cost of treatment for the experiment was as follows:

Petroleum treatment.—For this treatment 2 barrels of crude Texas petroleum shipped from Houston, Tex., costing $4.50 a barrel at Houston or $8.35 delivered at Levesque, Ark., were used. In addition to the oil, brushes and pails were used and a man was employed to put on the petroleum. The cost for the treatment may therefore be stated as follows:

Petroleum, 2 barrels, at $8.35 each	$16.70
Brushes and pails	5.00
Labor of 1 man, at $1.25 a day, for 8 days	10.00
Total	31.70
Cost per thousand feet	.1046

Creosote treatment.—For this treatment 2 barrels of coal-tar creosote were used. The cost of this treatment may be figured as follows:

Creosote, 2 barrels, at $5 each, delivered at Levesque	$10.00
Brushes and pails	5.00
Labor of 1 man, at $1.25 a day, for 8 days	10.00
Total	25.00
Cost per thousand feet	.0825

RESULTS OF TREATMENT TO PREVENT SAP-ROT.

The logs which had been treated were left on the river bank during the summer months. There was a heavy rainfall during August and September, and at times it was very hot. The conditions for the development of sap-rot were therefore very good. Two examinations were made of the logs, one in October and one in January.

PRELIMINARY EXAMINATION OF TEST LOGS.

A preliminary examination as to the condition of the logs given various treatments was made on October 31 and November 1, 1905. The following table shows the condition of the logs treated in the first series:

TABLE IV.—*Condition on October 31, 1905, of red gum logs at Marianna, Ark., which had received various treatments.*

Number of half log.	Treatment.	Notes on the condition of individual logs.
10800	Creosote	Free; checks very small.
10799	No treatment	Free; checks small.
10797	Creosote	Both ends free; enormous growths of *Polyporus adustus* all along one side of log.
10796	No treatment	Free; checks small.
10795	Creosote	Free.
10794	No treatment	One small *P. adustus* and much Schizophyllum on both ends.
10793	Creosote	Free; checks small.
10792	No treatment	Lower end of one side in wet sawdust.
10791	Creosote	Free; checks small.
10790	No treatment	Absolutely free from fungus; no checks.
10789	Creosote	Free; checks small.
10788	No treatment	Lots of Schizophyllum; very bad checks.
10786	Oil	Some fungus on one end; checks small.
10784	No treatment	*P. adustus* on one end; sap very black.
10783	Oil	Free; checks very small.
10782	No treatment	Very badly affected with *P. adustus* on one end and also on sides.
10781	Oil	Free; checks very small.
10780	No treatment	Free; checks very small.
10779	Creosote	Free; checks very small.
10778	No treatment	*P. adustus* slight on both ends near bottom; also some Schizophyllum; black sap.
10777	Creosote	Free; practically no checks.
10776	No treatment	*P. adustus* very bad on one end, lower side; sap looks black.
10775	Creosote	Schizophyllum, one spot on one end; checks slight.
10774	No treatment	Black sap; red spots both ends; no fungus.
10773	Creosote	Schizophyllum, one spot on one end; checks slight.
10772	No treatment	Schizophyllum, one spot on one end, checks slight.
10771	Creosote	No fungus; checks slight.
10770	No treatment	No fungus; checks slight.
10769	Creosote	Schizophyllum slight on one end; no checks.
10768	No treatment	Schizophyllum slight on one end; no checks.
10798	Creosote	Free; checks very small.
10787	No treatment	Small Schizophyllum on one end.

TABLE IV.—*Condition on October 31, 1905, of red gum logs at Marianna, Ark., which had received various treatments*—Continued.

Number of half log.	Treatment.	Notes on the condition of individual logs.
10767	Creosote	One very small patch of Schizophyllum on one end; checks slight.
10766	No treatment	One very small patch of Schizophyllum on one end; checks slight.
10765	Crude oil	Sound; no fungus.
10764	No treatment	Schizophyllum very slight on one end; none on other end; practically no checks.
10763	Oil	Schizophyllum very slight on one end; none on other; practically no checks.
10762	No treatment	Schizophyllum on one end; bad checks.
10761	Oil	Schizophyllum slight on one end; checks very small.
10760	No treatment	Schizophyllum on both ends; checks in sap; considerable sap black
10759	Oil	No fungus on either end; checks bad in heart on one end.
10758	No treatment	Enormous development of *P. adustus* on one end; no fruits on the other end.
10757	Oil	Free, and hardly any checks.
10756	No treatment	Free; absolutely no checks.
10755	Oil	Free on both ends.
10754	No treatment	Slight Schizophyllum; checks fairly large.
10753	Oil	Free; absolutely no checks.
10752	No treatment	Slight Schizophyllum; checks fairly large.

In a general way it may be stated that the outside appearance of the logs which had had creosote applied to the ends was superior to those logs which were treated with petroleum or those which had been left untreated. The creosoted ends looked reddish brown and were bright in color, with practically no sign of fungous growth. The logs treated with petroleum had a more or less dark appearance, with small patches of fungous threads here and there, none of which, however, had fruited to any extent when examined. The untreated logs as a rule had a black sapwood. Numerous fruiting bodies of the gray fungus (*Schizophyllum commune*) occurred here and there on the ends of the logs, and in several cases the fruiting bodies of the rot fungus (*Polyporus adustus*) were developing vigorously.

An examination of the logs treated in the second series showed a similar state of affairs. The creosoted logs were very striking in their appearance and could readily be picked out among all of the other logs. Those logs which were treated with petroleum appeared blackened, particularly on those ends which were not exposed to the sun, and many masses of fungous threads were growing on the surface of the sapwood. The odor of the petroleum was very distinct, showing that it was still present in considerable quantity. The untreated logs had unfortunately been coated with creosote about October 15, through a misunderstanding. Their appearance was therefore somewhat misleading, and no indications of fungi could be detected. In order to arrive at some conclusions as to what would have been their appearance had they not been thus coated, careful examination was made of a large number of top and butt logs, cut at about the same time the experimental logs were cut, which had remained in the forest and which were, of course, untreated. The general result of this

examination showed that the ends of such logs as were facing south or southwest were usually very dry and more or less checked. The ends not exposed to the direct action of the sun showed a darkly stained sap ring with the fruiting bodies of the rot fungus (*Polyporus adustus*) developing vigorously, sometimes in but one place and in other cases in ten or twelve places in the sap ring. This indicates that in untreated logs the growth of this fungus must begin very soon after the tree is felled and that a considerable amount of development takes place from August to the end of October, resulting in the formation of large masses of fruiting bodies by the end of that period.

A further difference which was very marked between the treated and untreated logs was the character and extent of the checking. The untreated logs as a rule checked much more than the treated logs. Some of the creosoted ends showed practically no checking, and where there was any checking it was as a rule very slight indeed.

FINAL EXAMINATION OF TEST LOGS.

The test logs were again examined on January 16, 1906. At this time most of the untreated logs showed more or less indication of rot at the ends. A large percentage of the untreated ends had masses of the sap-rot fungus (*Polyporus adustus*) growing profusely, generally near the lower side, where the log was close to the ground. The ends treated with creosote appeared black and smooth, without the slightest sign of fungous development. (Pl. V, fig. 2.) The ends treated with petroleum showed signs of disintegration, and in several cases fruiting forms of various wood-destroying fungi were growing on the treated ends.

The value of the creosote treatment in preventing the growth and development of the sap-rot fungi was shown very strikingly in these treated logs.

It should be noted, however, that almost all of the logs, irrespective of whether they were treated at the ends, showed a development of fruiting forms of the above-mentioned fungus (*Polyporus adustus*) growing out on the sides of the logs, chiefly on that side which touched the ground. In many cases the sheets of the fungus covered the bark for several square feet. When the bark was removed it was found that the wood under it was badly decayed, sometimes going half through the sapwood. Those logs which had been skidded so that the air circulated under them were practically free from fungous growth on the outside, although in several instances evidences were found that the fungus was actually growing under the bark and had simply failed to form fruiting organs on account of the drying out of the bark on the outside. No material difference could

be detected in the various logs treated with the creosote as regards checking. The smaller degree of checking of the end-treated logs compared with those which had not received any treatment was as striking at this examination as it had been in October.

An examination of the second set of logs treated at Levesqüe was made impracticable on account of the fact that they had been thrown into the water and the ends were generally covered with mud. As these were the logs which were sawed in the mill, however, a good idea as to the effect of the treatment was obtained while the logs were being sawed.

RESULTS SHOWN BY SAWED LUMBER.

The logs which had been treated in August at Levesque, Ark., were made into a raft the latter part of January, 1906. The raft was then towed from the landing to the sawmill. The logs remained in the water altogether for a period of about ten days. On arrival at the sawmill a particular effort was made to saw none but the test logs for two days. As the logs came up on to the log platform in the mill a record of the number was made, and the end of the log was so marked that when any particular log was placed on the saw carriage it was readily identified by the person who stood behind the resaw. Three grades of logs were marked, namely, the untreated logs, those treated with petroleum, and those treated with the creosote oil referred to. Each board as it left either the band saw or the resaw was marked in such a manner that when the boards or other lumber reached the grading table the graders had no difficulty in distinguishing between boards which came from either of the three sets of logs. The entire lot of experimental logs was cut into lumber. At the grading table this lumber was sorted and then placed in separate piles in the yard.

As the end treatment was made with the expectation that the development of the rot fungus might be stopped or at least greatly retarded by the application of the preservative to the ends of the logs, careful observation was made to see how far this treatment had succeeded by observing the logs as they were being sawed by the band saw. From the detailed notes kept at the time, the following general statements may be made: The untreated logs showed in a very striking manner how the fungus had gained entrance through both ends of the log and had grown gradually toward the center. The decay and discoloration extended into the log from either end anywhere from 1 to 3 feet. It certainly averaged 1½ to 2 feet. It was most marked within the first 6 or 8 inches and extended out in the peculiar zigzag lines already referred to. Another point which was noted was that not only did this decay start in from the end, but it was also very

marked for several inches in on all sides of the log except at such places where the bark had been accidentally torn away, particularly after the trees had been felled. The discoloration due to the growth of the fungus through the bark and thence inward through the sapwood varied with the log. Those which had a large percentage of sap showed a more marked degree of discoloration than those with less sap.

The logs which had been treated with petroleum showed the rot even more strikingly than the untreated logs. The first 2 or 3 inches in from the ends of the log were generally stained a dark brown or black. (See Pl. VI, fig. 2.) Going toward the middle of the log from the outer zone the decay followed into the log sometimes 3 feet or more. What has been said for the untreated logs in regard to the decay starting under the bark was true also for the petroleum-treated logs. The general observation made while the logs were being sawed was that the petroleum treatment had been a decided failure; in fact, the petroleum-treated logs seemed to have decayed even more than the logs which had been left untreated.

The logs treated with creosote showed a striking difference compared with both the untreated and the petroleum-treated logs. While the wood was frequently stained for some 2 to 3 inches at the very end, it was very noticeable that the wood beyond this outside stain looked sound and had a normal color. The characteristic discolored streaks found in decayed logs were markedly absent. (Pl. VI, fig. 1.) The decay caused by the entrance of the fungus through the bark, that is, along the sides of the logs, was about the same in the logs treated with creosote as in the untreated and petroleum-treated logs.

The general conclusions drawn from the observations made while the logs were being sawed were as follows:

(1) Decay had taken place with great rapidity in the untreated logs. The evidences of growth of the wood-destroying fungus were very marked on both ends of all logs, extending into the same for an average of about 2 feet.

(2) The logs treated with petroleum were badly stained for several inches in from each end, evidently owing to the growth of certain wood-staining fungi. In addition to the stain these logs were badly decayed at the ends for a distance of 2 feet or more, showing that the petroleum had evidently had no fungicidal value whatever.

(3) The creosote-treated logs were practically sound; in other words, the creosote had retarded or prevented the growth of the fungus, and logs the ends of which had been painted with creosote showed practically no evidences of any decay at either end.

As a result of the observations made while the logs were being sawed the conclusion was drawn that the creosote treatment had prac-

tically prevented the end-rotting of the red gum logs, and had thereby resulted in a considerable saving of lumber. This was very evident, because it was practically unnecessary to trim any of the boards which came from the creosoted logs, whereas the boards which came from untreated or petroleum-treated logs had to be trimmed sometimes for 2 feet or more at each end to cut off the decayed portion.

Because of these preliminary results, the lumber company has since that time been treating the ends of all its logs during the summer months by giving them a coating with coal-tar creosote, essentially as previously described, and the results obtained from the preliminary experiments just described have been borne out practically since that time.

REMOVAL OF BARK AS A PREVENTIVE MEASURE AGAINST SAP-ROT.

The experiments described in the foregoing pages dealt with the sap-rot as far as it attacked the logs from the ends. While the end sap-rot is usually the worst form of this rot, the disease is by no means confined to the cut surfaces of logs. After a log has been lying on the ground for some weeks, the bark dries more or less and small cracks will form here and there. Through these cracks the spores of the sap-rot fungus will enter, and in a short time the fungus will have begun decaying the wood, with this crack as a starting point. Various beetles will puncture the bark shortly after the trunks are felled, and spores will get in through the holes which they make. The bark prevents the evaporation of water from the wood, and after the sap-rot fungus has once entered the wood under the bark it finds almost ideal conditions for the most rapid growth and development. Logs which have been lying in the woods for several months will very frequently be decayed for from 1 to 6 inches through the sapwood, either in spots or throughout the entire length of the log. The longer a log lies in the woods the more advanced the decay will be. The sapwood of many logs will be wholly decayed after six months.

The growth of the sap-rot fungus can be very much retarded, if not entirely prevented, by peeling the logs as soon as possible after they are felled. Logs which have been peeled will dry out very rapidly, and when the outer layers are air-dried the chances for infection by the spores of the sap-rot fungus will have been reduced very materially. The peeling of logs is recommended wherever practicable for logs cut from April to November, the period when the trees are in a growing condition. Logs cut during the late autumn and winter will remain sound so long that peeling may be dispensed with.

REMOVAL OF SAP FROM FRESHLY CUT TREES BY LEAF SEASONING.

As was stated under an earlier heading, the wood of the living red gum is so full of water that it is impossible to float green logs. It is on this account that freshly cut logs have to be kept on the river banks until they are at least partially seasoned. If there was any method by which such logs could be dried out more rapidly, the chances for the development of the sap-rot fungus would be very materially reduced.

It is an old saying among lumbermen that logs can be dried by allowing the leaves to dry on a felled tree before sawing the tree into logs. While the writer has often heard this statement made, as far as it applies to felled logs he has so far been unable to find any place where this method has been or is being put to a practical test. The practice of girdling standing trees has practically the same effect. In the cypress forests of the South the trees are girdled in the early winter so as to cause a partial evaporation from the tops. When these logs are cut during the following summer a sufficient amount of water has evaporated from the standing trunks so that in a majority of cases the logs can be floated.

The red gum is a tree in which the drying out of the trunk by means of the leaves offers particularly favorable conditions. It was noted that when a green tree is cut down the leaves remain stiff and turgid for many days, and this even in the hottest weather in June and July. The explanation of this turgidity may be about as follows: When a tree is cut down the evaporation of water from the leaves will continue for a time, the duration of this evaporation depending upon the amount of water in the leaves. In most broad-leaved trees, owing to the fact that water evaporates from both the upper and lower surfaces, the leaves dry very soon after the tree is cut down. The rate at which water can pass from the smaller branches to the leaf petiole and thence to the leaf is very much slower than the rate at which the water evaporates from the leaf surfaces. As a result the leaves soon drop and dry up. In the red gum, however, only one of the surfaces of the leaf, the lower, is provided with stomates so that the evaporation of water takes place only from one surface and that the most protected one. The rate at which water passes from the trunk to the branches and thence in time to the smaller branches, leaf petioles, and the leaves is evidently very nearly the same as that at which the water evaporates from the leaf surface. For this reason the leaves remain green and turgid for a comparatively long time.

Taking this view of the case, the leaves may, in a crude way, be compared to so many little pumps which are slowly pumping the

water out of the trunks into the branches and out into the air. What the actual rate of evaporation from the leaves is, and how much water is actually removed from the trunks, is as yet unknown. Careful measurements to determine this fact are now in progress.

In order to see whether there was any practical result to be obtained by giving the leaves a chance to pump out as much water as they would, the following experiment was made during the past summer: About twenty-five trees were cut down in August, and instead of sawing the timber into logs immediately after felling them they were left intact until the leaves had become absolutely shriveled and dry. This took some two weeks or more. After that the trunks were cut into logs. These logs were skidded to the river just as other logs were skidded. One or more rolled down the bank, and instead of sinking, as a red gum log usually would after but two weeks' seasoning, these logs floated. They did not float very high out of the water; still they floated. The leaf-seasoned logs were made into a separate raft and were brought to the sawmill. It was noted that they floated 1 or 2 inches higher out of the water than was usually the case.

After they were sawed a number of boards were taken at random from the leaf-seasoned logs and a similar number from ordinarily seasoned logs. These were carefully measured and weighed, care being taken to separate sap and heart boards. The resulting average weights per cubic foot are shown in the following table:

TABLE IX.—*Weight per cubic foot of leaf-seasoned and ordinarily seasoned lumber.*

Leaf-seasoned lumber.		Ordinarily seasoned lumber.	
Sapwood.	Heartwood.	Sapwood.	Heartwood.
Pounds. 57.7	*Pounds.* 50.0	*Pounds.* 68.0	*Pounds.* 61.6

The results in this table show that the boards from leaf-seasoned logs were very much lighter than those from logs seasoned in the ordinary manner. Both heartwood and sapwood of the leaf-seasoned logs are lighter than water.[a] While the experiment is but a crude one, the results obtained therefrom are believed to be absolutely trustworthy. The testimony of experienced mill men who floated the leaf-seasoned logs bears out the evidence shown in the table. It may be objected that it will be an expensive matter to saw down trees and leave them to dry, and then to go back several weeks later to cut off

[a] Water at 62° F. weighs 62.355 pounds to the cubic foot.

the branches. While this is certainly true, the expense may be justifiable if one can reduce the time of holding the logs on the river bank and thereby reduce the chances of fungous attack.

The leaf seasoning may not always be practicable, but the results of the experiments of the summer of 1906 were so encouraging that extensive tests with red gum, tupelo gum, and water oak are now in progress.

OTHER SAP-ROTS OF THE RED GUM.

In addition to the sap-rot described in the preceding paragraphs, there are a number of other fungi which grow on the sapwood of the red gum with great rapidity.

HAIRY SAP-ROT (POLYSTICTUS HIRSUTUS).

Of the more important sap-rots the following may be mentioned:

Polystictus hirsutus (Wulff) Fries.

Boletus hirsutus Wulff Jacquin's Coll., 2: 149; 1795.

Polystictus hirsutus (Wulff) Fries (Syst. Myc., 1:367; 1836).

This fungus resembles in many respects the sap-rot fungus (*Polyporus adustus*) previously described. It appears very much as does this form on the ends of the freshly sawed boards (Pl. IV, fig. 3), on crossing strips, and on timbers. It is easily distinguished from the preceding form, however, by its marked zonated appearance on the upper surface of the fruiting body. The fruiting bodies are very much more distinct, although a large number may occur in groups on the same board, on the sides or on the ends. The upper surface of the fruiting body is very hairy (hence the name of the fungus), and is marked by a series of very distinct concentric zones, the alternate ones being a dark red-brown in color. The intervening ones are a yellowish color. The under side, instead of being a smoky brown, as in *Polyporus adustus*, is light straw-yellow. The pores, which in *Polyporus adustus* are very minute and practically indistinguishable to the naked eye, are very large and distinct in the fruiting body of the *Polystictus hirsutus*. When growing in the forest on tops and branches, this form may grow to be very large, sometimes 1½ to 2 inches in diameter, or even larger. Several hundred fruiting bodies are usually found together on old logs, where they form one of the most common fungi of the hardwood belt. *Polystictus hirsutus*, besides occurring on the red gum, is found on almost all species of oak, hickory, ash, maple, chestnut, and other hard woods. It is widely distributed over the eastern part of the United States and has been reported from South America and from several countries in Europe, Asia, and Australia.

The hairy fungus causes a form of decay in the sapwood of the red gum which is practically indistinguishable from that caused by *Polyporus adustus*. In manner of entering the logs, both through the ends and through the bark of the gum, it is similar to the sap-rot fungus. It differs from the latter in its rate of growth, which is by no means as rapid. In lumber piles it grows vigorously and forms fruiting bodies on the ends of boards, much as has been described for *Polyporus adustus*.

The preventive measures to be taken against this fungus are the same as for the sap-rot fungus. The two usually appear side by side, and for practical purposes they need not be separated.

PORIA SUBACIDA.[a]

The fungus *Poria subacida* Peck is frequently found on red gum boards after they have been stacked in piles. It is particularly common on the crossing strips, which it destroys rapidly. From the crossing strips the threads of the fungus grow into the boards on both sides and form sheets of white felt in the space between the boards and the crossing strip. The color of the red gum is destroyed by this fungus, so that after boards are removed from the stacks they will be discolored wherever they touched a crossing strip. Where boards lie in piles for a longer period this fungus may penetrate throughout the sapwood, which is in time reduced to a spongy, white, decayed mass. In the forest *Poria subacida* is found on old branches and tops. It is not of as much commercial importance, however, as either of the two fungi previously described. Where oak crossing strips are used little trouble should be experienced with this form.

OTHER FORMS CAUSING DECAY OF THE SAPWOOD.

While the four fungi already referred to are the ones most frequently found destroying the sapwood of the red gum, there are numerous others of minor importance. Among those are *Lentinus lecomtei* Fr.; *Lenzites betulina* (L.) Fries; *Lenzites bicolor* Fries; *Lenzites corrugata* Klotsch; *Polystictus cinnabarina* (Jacq.) Fr.; *Polystictus sanguineus* (L.) Meyer; *Schizophyllum commune* Fries; *Poria vaporaria* Fr.; *Polystictus versicolor* (L.) Fr.; *Polystictus gilvus* Schw.; *Polystictus pergamenus* Fr.; *Trametes sepium* Berk.; *Stereum fasciatum* Schw.; *Stereum gausapatum* Fries.

[a] Rept. New York State Botanist, 38: 92; 1884.

DECAY OF THE HEARTWOOD OF THE RED GUM.

As was stated in a previous paragraph, the heartwood of the red gum has a length of life very much greater than is usually believed. While this timber has not been used to any very large extent until recent years, its comparatively high resisting power to atmospheric disintegration and to fungous attack should make it an increasingly valuable wood for many purposes requiring exposure to weathering action. Plate VII, figure 1, shows a section of a cross arm which had been exposed on an electric light line for eight years. It will be noted that the arm is still in almost perfect condition. Plate VII, figure 2, shows a section of a red gum cross-tie which had been in constant service in a road in northern Louisiana. About 1,500 ties of heart red gum were laid in 1897. After five years 30 per cent were removed, and at the end of six years 15 per cent more were taken out. In the year 1906 there were 20 per cent still in service. The average life, therefore, was about 7½ years. This is practically as long and, in fact, somewhat longer than white oak would have lasted, when one takes into account the fact that the region where the ties were in service is one of high rainfall and subtropical temperature. The section of cross-tie illustrated in Plate VII, figure 2, shows the beginning of decay at the bottom, but the wood is still comparatively sound for the larger part.

Similar instances of long life have been frequently recorded for the heartwood of the gum where it has been used for paving blocks, foundation timbers, piling, and other purposes requiring longevity. So far as known to the writer there is only one fungus which actively attacks the heartwood and destroys it, and this form does not seem to be at all common. The decay induced by *Lenzites vialis* Peck changes the wood of the gum into a dry, brittle mass, which can be rubbed into a fine powder when pressed between the fingers. The spores of the fungus enter the wood through season checks. On Plate VIII, figure 1, is shown an end view of a tie which had served a great many years in one of the southern railroads. The fruiting bodies of the fungus are developed on this timber. Plate VIII, figure 2, shows a section of this tie 6 inches in from the end. It will be noted that it is almost entirely decayed, with the exception of the region immediately exposed to the air.

Of other heart-rot fungi, only two need be mentioned: *Polyporus lacteus*, and what appears to be an undescribed species of Trametes.

SAP-ROT OF THE TUPELO GUM, SWAMP OAK, AND MAPLE.

The sapwood of many other trees is destroyed by various fungi in a manner very similar to that described for the sapwood of the red gum. In the region of the Mississippi Valley the timbers which

are particularly affected by the sap-rot in addition to the red gum are the tupelo gum, swamp oak, and maple. Of these three timbers, the tupelo gum is the one which is most seriously affected. The trees are attacked by a number of sap-rotting fungi very shortly after they are felled, particularly if the trees are cut in the months from March to October. The rate of destruction of the sapwood by these fungi far exceeds that found for the sapwood of the red gum. The destruction of the sapwood of the tupelo gum by these fungi is so serious that it has been found impossible to pile logs of tupelo gum on the banks of southern rivers for the purpose of drying them so that they can be floated during the months from March to October; wherever such piling has been tried the sapwood has rotted so rapidly that the timber was rendered practically valueless. The fungi which are pacticularly active in destroying the sapwood of the tupelo gum are the following: *Polyporus hirsutus*, *Polyporus versicolor*, and *Polyporus cinnabarina*. Extensive experiments are now in progress, the object of which will be to devise a method for reducing the destructive effects of these forms.

SUMMARY AND RECOMMENDATIONS.

1. The sapwood of the red gum is destroyed with great rapidity by several sap-rotting fungi. The decay caused by these fungi may be called "sap-rot."

2. These fungi grow most rapidly during the spring and summer months. They enter mainly through the ends of logs piled on the banks of rivers.

3. Sap-rot may be prevented by shortening the drying period in the woods, either by hauling logs by rail or by reducing the moisture in the log. This may possibly be accomplished by felling the gum trees without sawing them into logs and leaving them in the forest until the leaves are thoroughly dry. The amount of water evaporated by the leaves before they dry may be sufficient to permit of floating the logs cut from such leaf-seasoned trees.

4. The sap-rot may likewise be almost entirely prevented by coating the ends immediately after the logs are cut with hot coal-tar creosote. The cost of this treatment is about 8 cents a thousand feet, board measure.

5. Wherever possible all freshly cut logs, particularly such as are cut during the spring and summer months, should be peeled.

6. The heartwood of the red gum is comparatively resistant against decay.

7. Sap-rots similar to those which are found in the red gum are found in the tupelo gum, swamp oak, and maple.

PLATES.

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DESCRIPTION OF PLATES.

PLATE I. Heart-rots of living red gum. Fig. 1.—Radial section of heartwood of red gum affected with yellow butt-rot. Fig. 2.—Tangential section of heartwood of red gum affected with speckled rot.

PLATE II. Untreated red gum logs affected with sap-rot. Fig. 1.—Top of red gum log which has been lying in the woods for two summer months, showing blackened sapwood. Fig. 2.—Red gum log which has been lying in the woods for five warm months, showing large numbers of fruiting bodies of the sap-rot fungus (*Polyporus adustus.*)

PLATE III. Sap-board of red gum affected with sap-rot. The upper part of the figure shows the normally colored wood of the gum. The lower, bleached part of the figure represents the end of the board and shows how the fungus discolors it.

PLATE IV. Fruiting bodies of fungi causing sap-rot of red gum, photographed from boards in lumber piles. Fig. 1.—Sap-rot fungus (*Polyporus adustus*) growing on ends of red gum lumber in pile for eight weeks. Fig. 2.—Sap-rot fungus (*Polyporus adustus*) growing on red gum board in pile for eight weeks. Fig. 3.—Hairy sap-rot fungus (*Polystictus hirsutus*) on red gum in pile for three months.

PLATE V. Red gum logs showing effect of creosote treatment. Fig. 1.—Yard of logs at Levesque, Ark., five months after treatment. Fig. 2.—Logs five months after treatment, showing total absence of sap-rot.

PLATE VI. Red gum boards showing effect of treatment with creosote and with petroleum. Fig. 1.—Two boards cut from different logs treated with coal-tar creosote. The ends of the respective boards face each other. Fig. 2.—Two boards cut from logs treated with petroleum. The ends of the respective boards face each other.

PLATE VII. Heartwood of red gum after eight years' service. Fig. 1.—Section of cross-arm. Fig. 2.—Railroad cross-tie from northern Louisiana.

PLATE VIII. Heartwood of red gum affected with rot. Fig. 1.—Heart-rot fungus (*Lenzites vialis*) growing on heartwood of red gum. Fig. 2.—Cross section of railroad cross-tie made of heartwood of red gum, showing destruction caused by *Lenzites vialis*.

FIG. 1.—YELLOW BUTT-ROT.

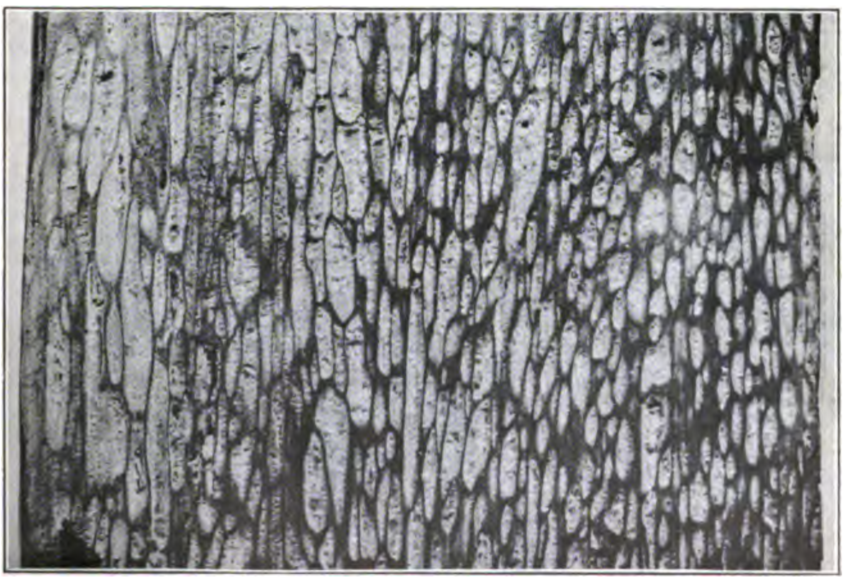

FIG. 2.—SPECKLED ROT.

HEART-ROTS OF LIVING RED GUM.

FIG. 1.—LOG AFTER LYING TWO SUMMER MONTHS IN THE WOODS.

FIG. 2.—LOG AFTER LYING FIVE WARM MONTHS IN THE WOODS.

UNTREATED RED GUM LOGS AFFECTED WITH SAP-ROT.

SAP-BOARD OF RED GUM AFFECTED WITH SAP-ROT.

FIG. 1.—SAP-ROT FUNGUS (POLYPORUS ADUSTUS) GROWING ON THE ENDS OF RED GUM LUMBER IN PILE.

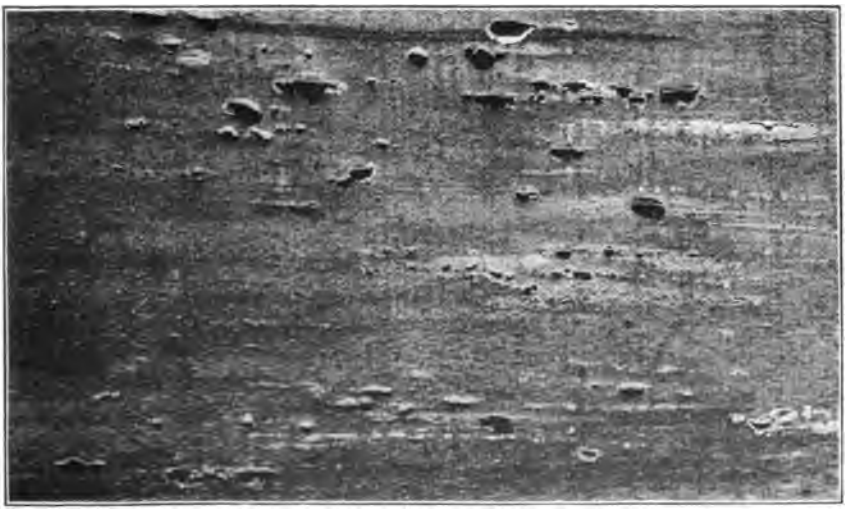

FIG. 2.—SAP-ROT FUNGUS (POLYPORUS ADUSTUS) GROWING ON A BOARD OF RED GUM IN PILE.

FIG. 3.—HAIRY SAP-ROT FUNGUS (POLYSTICTUS HIRSUTUS) ON RED GUM IN PILE.

FRUITING BODIES OF FUNGI CAUSING SAP-ROT OF RED GUM.

FIG. 1.—YARD OF LOGS FIVE MONTHS AFTER TREATMENT.

FIG. 2.—LOGS FIVE MONTHS AFTER TREATMENT, SHOWING TOTAL ABSENCE OF SAP-ROT.

RED GUM LOGS, SHOWING EFFECT OF CREOSOTE TREATMENT.

FIG. 1.—BOARDS TREATED WITH COAL-TAR CREOSOTE.

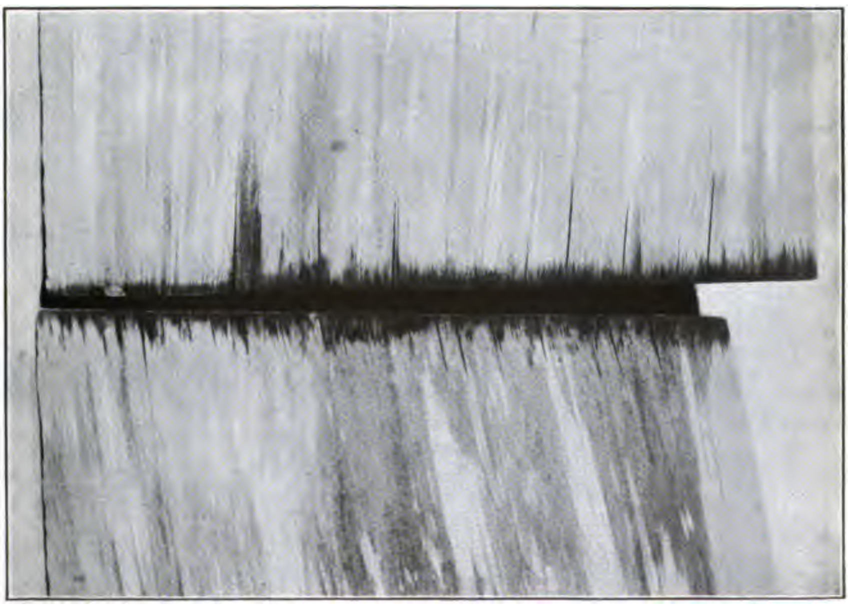

FIG. 2.—BOARDS TREATED WITH PETROLEUM.

RED GUM BOARDS, SHOWING EFFECT OF TREATMENT WITH CREOSOTE AND WITH PETROLEUM.

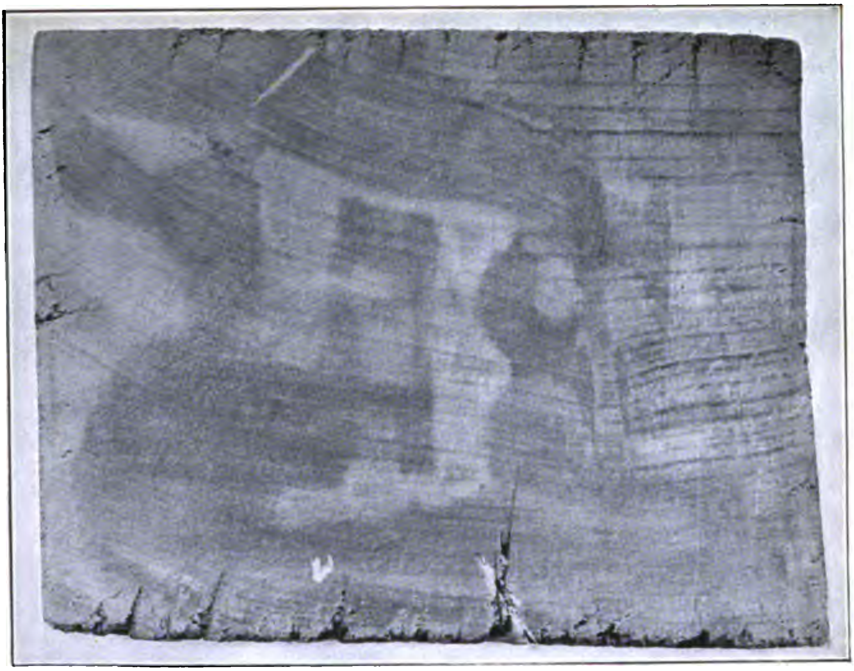

FIG. 1.—SECTION OF CROSS-ARM.

FIG. 2.—RAILROAD CROSS-TIE FROM NORTHERN LOUISIANA.

HEARTWOOD OF RED GUM AFTER EIGHT YEARS' SERVICE.

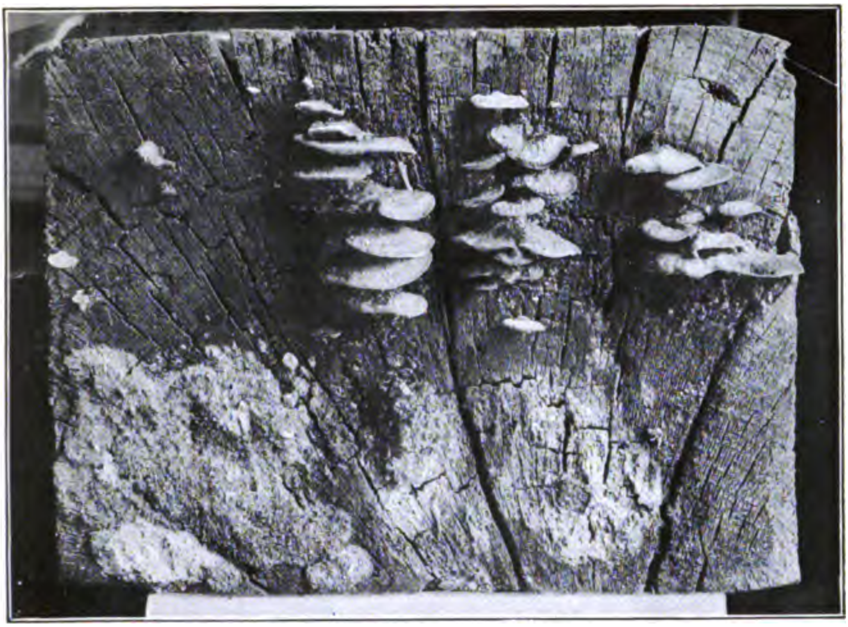

FIG. 1.—HEART-ROT FUNGUS (LENZITES VIALIS) GROWING ON HEARTWOOD OF RED GUM.

FIG. 2.—RAILROAD CROSS-TIE, SHOWING HEART-ROT CAUSED BY LENZITES VIALIS.

HEARTWOOD OF RED GUM AFFECTED WITH ROT.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 115.

B. T. GALLOWAY, *Chief of Bureau.*

THE DISINFECTION OF SEWAGE EFFLUENTS FOR THE PROTECTION OF PUBLIC WATER SUPPLIES.

BY

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ISSUED OCTOBER 15, 1907.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., August 1, 1907.

SIR: I have the honor to transmit herewith a paper entitled "The Disinfection of Sewage Effluents for the Protection of Public Water Supplies." This deals with a subject of vital importance to sanitarians interested in the protection and purification of water supplies, and I recommend that it be published as Bulletin No. 115 of the series of this Bureau.

This paper was prepared by Mr. Karl F. Kellerman, Physiologist in charge of Water Purification Investigations, in cooperation with Mr. R. Winthrop Pratt, chief engineer of the Ohio State board of health, and Mr. A. Elliott Kimberly, special assistant engineer of the Ohio State board of health and collaborator of this Bureau. The Department of Agriculture has been fortunate in its cooperation with the Ohio State board of health, and I wish to add a word of personal appreciation of the keen interest and enthusiasm shown by Dr. C. O. Probst, the secretary of the board, and his associates, Mr. Pratt and Mr. Kimberly, in the prosecution of this work.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE DISINFECTION OF SEWAGE EFFLUENTS FOR THE PROTECTION OF PUBLIC WATER SUPPLIES.

INTRODUCTION.

Of the many points in connection with the disposal of sewage there is, perhaps, none that has recently received more attention than the question of the degree of purification that should be required before a sewage effluent is discharged into a stream or other body of water which serves as a source of water supply. It is unnecessary here to take up in detail the various standards or general recommendations that have been made, especially as it is becoming more widely recognized that for every locality there should be established an individual standard which in the case of certain conditions might require no purification and which under certain other conditions might require the removal of all bacteria likely to cause disease, in addition to the greatest possible chemical improvement of the sewage effluent.

Some investigators [a] consider that the purification of a sewage to the nonputrescible point or point of chemical stability is sufficient, basing their conclusion upon the fact that all polluted waters and perhaps all surface waters should be subjected to filtration for the purpose of removing disease germs. The logical conclusion of this point of view has been stated in these very emphatic words, "If the people below select to drink the sewage of the people above, surely they should be held responsible for the cost of manipulating it to their fancy." [b] It would seem, however, that while the plan suggested,[c] to divide the cost of elaborate sewage treatment between

[a] Winslow and Phelps. Investigations on the Purification of Boston Sewage. U. S. Geol. Survey, Water-Supply and Irrigation Paper 185, 1906.

[b] Reid, George. To what Extent must Authorities Purify Sewage? Surveyor and Municipal and County Engineer, vol. 31, No. 788, pp. 274–275; discussion, pp. 275–278. London, February 22, 1907.

[c] Digby, W. Pollard, and Shenton, Henry C. H. Prevention of the Bacterial Contamination of Streams and Oyster Beds. London, published by the Society of Engineers, 1906. [The same, very slightly abridged] Surveyor and Municipal and County Engineer, vol. 30, No. 777, pp. 653–655, December 7; No. 778, pp. 685–688, December 14; discussion, pp. 688–690. London, 1906.

the sewage disposal plant and the water filtration plant affected by the sewage disposal, might be productive only of legal complications, there is a broader interpretation of the principles of public health which not only makes such expenditures a moral obligation on the part of the sewage disposal authorities, but because of these expenditures may show a marked financial gain for the entire community. There can be no doubt that the responsibility of furnishing pure water should fall exclusively upon the company or municipality controlling the water supply, but the degree to which the adjacent sewage disposal plants should aid in protecting a source of supply from pollution should be determined by some unprejudiced central authority. It should be possible also for this same central authority to have jurisdiction over the operation of sewage disposal plants and water purification plants.

It is indisputable that there is much pollution of streams not caused by sewage effluents[a] and that water purification, rather than sewage purification, is in general the essential point in protecting water consumers.[b] Where sewage is rendering a water supply exceedingly dangerous, however, either the water must be disinfected[c] before being distributed to the consumers or, according to what is the more logical first step in economic and æsthetic purification of the water, the polluting sewage must be purified and at least partially disinfected before it is discharged into the stream or lake in question. Filtration of the water supply would almost certainly be required in either case.

Chemical treatment for the sterilization of sewage has often been suggested. A review of the literature, however, shows that in general early attempts were based upon the treatment of crude sewage, the sterilization of which is of course usually more of a disadvantage than an advantage. During the last few years the more scientific principle of disinfecting, not sterilizing, a sewage effluent which has been carried to a fair degree of chemical purity has become more popular and has even been suggested as an aid in emergencies where a city's water supply is dangerously polluted.

In the experiments on the disinfection of sewage effluents to be discussed in this bulletin, copper sulphate and chlorin, two of the most promising of the germicides suggested for disinfecting sewage and water, were experimented with at some length and under as varied conditions as possible.

---

[a] Leighton, M. O., River Pollution. Proc. American Water Works Assn., 26th Conv., pp. 61–71; discussion, pp. 71–78.. 1906.

[b] Baker, M. N. Notes on Sewage Purification and Public Water Supplies. Proc. American Water Works Assn., 26th Conv., pp. 51–56; discussion by W. P. Mason, pp. 57–58. 1906.

[c] Whipple, George C. Disinfection as a Means of Water Purification. Proc. American Water Works Assn., 26th Conv., pp. 266–280. 1906.

Copper sulphate has been used to disinfect crude and settled sewage before filtration;[a] it has also been used to eradicate troublesome algæ from sewage filters,[b] and its use has been suggested for disinfecting sewage effluents,[c] although extensive tests of its applicability to the latter purpose are lacking.

COPPER SULPHATE EXPERIMENTS.

Our own experiments upon the germicidal effect of copper have been planned to include sewage effluents of different qualities, ranging from highly purified effluents from sand filters to the putrescible effluents from septic tanks. Westerville, The Boys' Industrial School, Lancaster, and Marion, Ohio, were selected for substations, and a preliminary experiment upon fresh sewage was conducted at St. Mary's of the Springs, near Columbus, Ohio.

ST. MARY'S OF THE SPRINGS.

St. Mary's of the Springs is a convent school located near the city of Columbus and has a population of about 175 persons. The sewage from this institution at the present time is discharged into two tanks operated in series. These tanks are 10 feet in diameter and about 6 feet in depth to the flow line; the capacity of each is about 3,050 gallons. Recent measurements indicate that the flow of sewage is in the vicinity of 12,000 gallons for a period of 16 hours, there being practically no flow after 10 o'clock p. m. The sewage discharges from the second tank into a small brook through 12 feet of 8-inch tile. Generally speaking, the plant comprises two reservoirs which retain some of the coarser solids; the first tank contains a thin scum and considerable accumulated sludge; the second shows no scum formation; the sewage as discharged is, of course, highly putrescent.

Dating from about Septemper 1, 1905, it has been the daily practice of the health department of the city of Columbus, Ohio, to apply copper sulphate to the sewage at the inlet of the second reservoir. The quantity of copper sulphate added daily is said to be 6 pounds,

[a] Newcomb, Edwin L. Copper Sulphate as an Adjunct to Sewage Disposal. Jour. New England Water Works Assn., December, 1905.

[b] The Use of Copper Sulphate at Pawtucket, R. I., to Prevent the Clogging of Sewage Filter Beds by Blanket Growth of Microorganisms. (From the November-December Bul. of the Rhode Island State Board of Health), Engineering News, vol. 57, No. 14, pp. 379–380, 2 figs. New York, April 4, 1907. The same, Engineering Record, vol. 55, No. 13, pp. 413–414, illus. New York, March 30, 1907.

[c] Indian Government. Resolutions on the Working of Septic Tanks. Calcutta, January 6, 1906.

Johnson, George A. Report on Sewage Purification at Columbus, Ohio, Made to the Chief Engineer of the Board of Public Service. Columbus, Ohio, 1905, pp. 471–479.

Rideal, Samuel. Sewage and Bacterial Purification of Sewage. 3d ed., London and New York, 1906, p. 174.

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3 of which are introduced at 9 a. m., the remainder at 3 p. m., roughly approximating a concentration of 63 parts to the million. The copper sulphate in a dry state is placed in a perforated enameled pail, which is then lowered into the liquid to a point opposite the discharge pipe from the first reservoir. The copper sulphate remains suspended here, exposed to the somewhat erratic solvent action of the incoming sewage; at times it is found that the entire quantity of chemical used for one day's dose is not completely dissolved in twenty-four hours.

In making an examination of this plant samples of untreated sewage entering the second tank and of treated sewage leaving the second tank were collected at half-hourly intervals for a period of seven hours on two successive days. Tubes were inoculated and plates were poured in the field in order that the bacterial analysis for the determination of total numbers, acid formers, and the identification of the latter with respect to *Bacillus coli* [a] might be more accurate. All tests were carried through in duplicate. In addition to the collection of samples, measurements of the sewage flow were made at half-hourly intervals.

Table I shows the results of these examinations. From an average of 16 samples of effluent collected on the two days the total number of bacteria to the cubic centimeter developing within forty-eight hours at 20° C. was 5,600,000 for the raw and 65,000 for the treated sewage, giving a reduction of approximately 99 per cent. Platings of the treated effluent when incubated at 37° C. for a period of twenty-four hours averaged 250,000 colonies, of which 36,750, or 14.7 per cent, were acid producing, the majority being *Bacillus coli*. Unfortunately no tests were made to learn the bacterial content of the raw sewage at an incubation temperature of 37° C., and it is impossible to determine whether the percentage reduction of bacteria capable of growing at 37° is greater than that of the development at 20° C., though from past experience this seems reasonable.

TABLE I.—*Results of bacterial analyses of sewage effluents, St. Mary's of the Springs, Ohio.*

Date.	Sampling period.	Bacteria to the cubic centimeter.[a] Untreated sewage.	Treated sewage.	Bacteria removed.
1906.				*Per cent.*
September 17	9.30 a. m. to 4.30 p. m.	5,900,000	60,000	98.99
September 18	8.15 a. m. to 3.15 p. m.	5,300,000	70,000	98.89

[a] Averages of half-hourly duplicate analyses. Incubated at 20° C.

The cost of treating the settled sewage of St. Mary's of the Springs is practically the cost of chemicals and the cost of maintenance, as

[a] Carried through *B. coli* identification recommended by the American Public Health Association.

the construction costs for the plant are practically negligible. With copper sulphate at 6 cents a pound and a daily sewage flow of 12,000 gallons the expenditure for chemicals is 3 cents for each 1,000 gallons, using 6 pounds of copper sulphate a day. The labor cost may be considered to be 25 cents a day. Similar plants applying copper sulphate in the proportion of 63 parts to the million to a sewage flow of 12,000 gallons would require about 6 pounds of copper sulphate daily, costing 36 cents a day. On an annual basis, including labor for one hour a day at 25 cents an hour, the chemical and maintenance cost would be about $222.65, proportioned as follows:

2,190 pounds of copper sulphate, at 6 cents a pound	$131.40
Labor, 365 hours, at 25 cents an hour	91.25
Total	222.65

Capitalized at 5 per cent, this would represent an investment of $4,500.

For crude sewage much better results could probably be obtained by using 100 parts of copper sulphate to each million parts of sewage. For treating 12,000 gallons of sewage at this rate the expense would be 60 cents a day, or $310.25 annually, and the corresponding capitalization would be $6,200.

WESTERVILLE.

The sewage plant at Westerville,[a] Ohio, comprises two small septic tanks which discharge, through an aerating device, on to six primary cinder contact filters, which in turn discharge upon two secondary filters. The plant at the present time is operated continuously, instead of upon the contact principle. The effluent from the primary filters is usually nonputrescible, but at times tends to become unstable and contains considerable crude organic matter. As the effluent from the primary filters was the more accessible, by suitable piping it was conducted through an orifice box where the proper quantity could be diverted for the experiments with copper treatment, the excess being discharged over a waste weir. During this test the flow of sewage was such that the additional head due to the discharge over the waste weir was probably not sufficient to influence measurably the computed discharge of 41,000 gallons in twenty-four hours.

The copper crystals were dissolved in barrels connected in series. The solution in the barrels was conducted to an orifice box, where by means of a ball cock a constant head was maintained upon an adjustable orifice. The quantity of copper sulphate used in each test was based upon the computed flow of 41,000 gallons of effluent in twenty-four hours. The water which was used for dissolving the

[a] For description, see Annual Report Ohio State Board of Health, 1903, p. 560.

copper salt had such a high alkalinity that it was necessary to almost neutralize the carbonates with sulphuric acid before preparing the copper-sulphate solutions, as otherwise the copper would be completely precipitated in the solution tanks. After passing through the orifice box the copper solution was discharged into a small storage reservoir at the same point where the discharge from the sewage effluent orifice box was admitted; the rate of discharge was 0.5 gallon a minute. The concentration of the applied copper solution, of course, varied with the different concentrations studied. At the point of entrance of the sewage effluent and the copper solution there was placed a small longitudinal baffle, serving to effect a thorough mixture of the chemical and the effluent. The storage period, or time of contact of sewage and copper sulphate, was slightly over one hour.

At hourly intervals during the test bacterial samples of the sewage effluent were collected before and after treatment. Samples for chemical analyses were collected at hourly intervals, and the composite sample so obtained was subjected to chemical analysis. In addition, determinations were made in the field for free carbonic acid and for alkalinity before and after treatment.

The initial run was made at a concentration of 5 parts to the million, followed by gradually increased amounts of the chemical until a concentration of 67 parts to the million was reached. It was the general practice to apply copper sulphate at a given concentration for two consecutive days. As will be seen from Table II, the percentage of removal of bacteria grown at 20° C. varied from 95 per cent to 59 per cent, depending upon the concentration of copper sulphate applied and also upon changes in temperature.[a] The removal of bacteria developing at 37° C. was much more erratic than was the case at 20° C., the percentage of removal varying between 28 and 96 for total numbers and between 66 and 100 for acid-producing bacteria. The different concentrations of copper sulphate that were used showed less variation in efficiency than might have been expected.

[a] Moore, G. T., and Kellerman, K. F., Bul. 76, Bureau of Plant Industry, p. 12, 1905. Johnson, George A., Report on Sewage Purification at Columbus, Ohio, Appendix X, p. 478, 1905.

TABLE II.—*Volume of flow, temperature, organic and suspended matters, and efficiency of copper sulphate applied, Westerville, Ohio.*

Date.	Copper sulphate, parts per million.	Volume of effluent treated.	Temperature. Air.	Temperature. Effluent.	Parts per million. Carbonic acid. Free. Untreated effluent.	Free. Treated effluent.	Half bound. Untreated effluent.	Half bound. Treated effluent.	Oxygen consumed.	Nitrogen as— Organic.	Free ammonia.	Nitrites.	Nitrates.	Suspended matter. Total.	Suspended matter. Volatile.	Putrescibility.	Bacteria per cubic centimeter. 20° C. Untreated effluent.	20° C. Treated effluent.	37° C. Total count. Untreated effluent.	Total count. Treated effluent.	Red colonies. Untreated effluent.	Red colonies. Treated effluent.	Bacterial removal. 20° C.	37° C. Total colonies.	37° C. Red colonies.	Per cent positive with test for *B. coli.* Untreated effluent.	Treated effluent.
1906.		*Galls.*	° C.	° C.																			*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Oct. 2	5	41,000	21.0	18.0	34	23	194	198	14	3.5	7.0	0.068	0.015	44	23	+	3,100,000	205,000	83,000	207,000	10,000	1,100	94	−149	89	13	67
3	5	41,000	18.5	17.5	43	26	220	229	12	1.3	8.0	.18	1.0	35	16	+	9,100,000	2,100,000	205,000	42,000	1,400	100	77	80	93	27	63
5	6.7	41,000	22.5	18.0	40	32	210	209	15	9.7	6.0	.16	1.0	24	6	+	430,000	120,000	20,000	14,500	6,500	325	73	28	95	33	45
6	6.7	41,000	13.9	16.0	40	32	177	178	9	2.5	9.0	.21	1.5	37	27	+	69,000	24,000	18,000	5,500	6,000	1,400	66	70	77	21	67
9	10	41,000	7.5	12.0	28	27	192	191	5	1.3	6.4	.16	1.5	26	19	+	75,000	16,000	66,000	11,000	3,400	1,500	79	84	66	5	22
10	10	41,000	4.0	10.0	26	24	202	210	6	1.1	6.0	—	1.8	16	9	+	46,000	16,500	28,000	8,000	1,800	450	65	72	75	—	18
15	13	41,000	23.5	15.0	36	30	230	236	6	1.1	7.2	.20	1.7	10.4	9.6	+	60,000	25,000	25,000	4,000	2,500	250	59	84	90	—	40
16	13	41,000	23.5	15.5	37	32	238	238	7	1.9	8.0	.17	1.5	10.0	8.8	+	70,000	20,000	48,000	7,000	6,600	900	72	86	87	—	82
19	20	41,000	18.0	16.0	35	33	218	214	15	4.9	4.0	.18	1.7	16.0	8.8	+	145,000	26,000	87,000	12,500	1,600	110	82	86	93	—	6
20	20	41,000	17.5	15.5	32	30	221	216	12	3.3	5.6	.18	1.5	7.6	3.6	+	88,000	13,000	69,000	10,000	1,500	110	85	86	93	—	38
25	29	41,000	8.0	14.0	40	36	202	119	14	4.6	8.8	.08	0.8	34	15	+	60,000	3,900	24,000	6,000	1,200	10	75	75	99	—	33
26	40	41,000	12.0	14.5	40	38	211	201	10	3.9	9.0	.07	0.7	36	32	+	60,000	6,200	50,000	3,000	2,500	15	94	94	99.5	—	66
Nov. 3	40	41,000	14.0	13.0	41	39	176	173	15	1.5	11.0	.07	0.5	17	17	+	370,000	7,000	130,000	6,000	3,000	00	95	96	100	—	—
5	40	41,000	19.5	14.0												+	46,000	13,000	51,000	5,000	11,000	300	91	91	97	—	62
8	67	41,000	19.5	13.0	41	40	218	214	39	5.1	10.0	.03	0.2	30	—	+	175,000	47,000	115,000	16,000	7,700	800	86	87	88	—	41
9	67	41,000	16.0	13.5	39	38	210	206	16	3.9	10.0	.05	0.0	36	—	+	220,000	21,500	47,000	12,000	6,500	600	74	75	91	—	33

On the basis of treating daily 41,000 gallons of effluent from the primary contact filters, the initial cost of a plant for applying the germicidal chemical would be $70 in round numbers. Considering a satisfactory removal of pathogenic organisms to be produced by a concentration of 40 parts to the million, the daily quantity of copper sulphate required would be 13.7 pounds; the cost for chemicals would be about 82 cents and for 2 hours' labor, 50 cents. The annual cost with copper sulphate at 6 cents a pound and labor at 25 cents an hour would then be as follows:

5,000 pounds of copper sulphate at 6 cents a pound	$300.00
Labor, 730 hours at 25 cents an hour	182.50
Total	482.50

Capitalized at 5 per cent, this would represent an investment of $9,650.

BOYS' INDUSTRIAL SCHOOL, LANCASTER.

The Boys' Industrial School[a] is a State institution located near Lancaster, Ohio, and has a population of about 1,100 persons. The sewage from the institution is treated on twenty-three intermittent sand filters which receive the crude sewage which has been subjected only to rough screening as a preliminary treatment. The sewage flow at the institution, from measurements made by the State board of health, averages about 160,000 gallons in twenty-four hours. In carrying out the copper experiments at Lancaster, in distinction from applying a constant quantity of copper sulphate to a constant quantity of effluent, as was the case at Westerville, it was thought most practicable to apply the chemical to the entire effluent flow, carrying out the experiments with a view to learning the quantity of copper sulphate required to destroy coli-like organisms when the sewage effluent was flowing at a maximum rate.

The effluent from the sewage filter discharges into a 20-inch main collecting drain, which also serves in times of storms to carry off storm water from some of the neighboring hills. At the outlet of the effluent drain a weir was constructed having a length of 1 foot and a height of 15 inches. Over this the sewage effluent was caused to flow. Suitable means were provided for observing the elevation of water on the crest of the weir. The effluent drain from the sewage plant discharges into a small brook in which a dam was constructed about 200 feet from the weir. This improvised reservoir gave a storage period of from three to four hours, depending upon the rate of flow from the filters.

The quantity of copper sulphate applied was based upon a sewage flow of 150,000 gallons during the hours the experiments were con-

[a] For description, see Annual Report Ohio State Board of Health, 1903, p. 515.

ducted, and at the beginning of the test was calculated to afford a concentration of 5 parts to the million. The rate of flow of the copper solution was practically constant at 0.75 gallon a minute, but the flow of the sewage effluent varied widely; consequently the resulting concentration of copper sulphate showed the same variations.

Bacterial and chemical samples of the effluent before and after treatment, respectively, were collected at hourly intervals, as at Westerville. They were examined for total numbers and for colonies developing at 37° C. Determinative tests for *Bacillus coli* were carried out by fishing three colonies from one of the duplicate plates of each hour's series for both the untreated and treated effluent. As the concentration of the copper sulphate increased and the bacteria began to decrease this procedure was not rigidly followed, and in the case of small development all of the acid-forming colonies were subcultured. All of the bacterial work was carried out in the field, including the sterilization of plates and the subculture work.

The concentration of copper sulphate applied was increased on each successive run until a maximum of 20 parts to the million was reached, based on a flow of 150,000 gallons. From the fifteen-minute weir readings the average flow of effluent was computed, and from these data the actual average concentration of the copper sulphate on a given day was determined. These results are recorded in detail in Table III.

Careful study of Table III shows that from the public-health standpoint the treatment at Lancaster was more satisfactory than either of the two preceding cases. The percentage of removal of bacteria developing at 20° C. was in one case lower, but the removal of the bacteria developing at 37° C. was much greater and the elimination of acid colonies and *Bacillus coli* was almost complete. The more efficient action of copper sulphate at Lancaster is undoubtedly due to the better chemical condition of the sewage effluent, especially its greater freedom from organic matter[a] and its freedom from carbonates.

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[a] Johnson, George A. Report on Sewage Purification at Columbus, Ohio, 1905, p. 474.

TABLE III.—*Volume of flow, temperature, carbonic acid, organic and suspended matters, and efficiency of copper sulphate at different concentrations, Boys' Industrial School, Lancaster, Ohio.*

Date.	Copper sulphate (parts per million). Maximum.	Copper sulphate. Minimum.	Copper sulphate. Average.	Volume of effluent. Maximum.	Volume of effluent. Minimum.	Volume of effluent. Average.	Temperature. Air.	Temperature. Effluent.	Parts per million. Carbonic acid. Free. Untreated effluent.	Carbonic acid. Free. Treated effluent.	Carbonic acid. Half bound. Untreated effluent.	Carbonic acid. Half bound. Treated effluent.	Oxygen consumed.	Nitrogen as— Organic.	Nitrogen as— Free ammonia.	Nitrogen as— Nitrites.	Nitrogen as— Nitrates.	Suspended matter. Total.	Suspended matter. Volatile.	Bacteria per cubic centimeter. 20° C. Untreated effluent.	20° C. Treated effluent.	37° C. Total count. Untreated effluent.	37° C. Total count. Treated effluent.	37° C. Red colonies. Untreated effluent.	37° C. Red colonies. Treated effluent.	Bacterial removal. 20° C.	Bacterial removal. 37° C. Total colonies.	Bacterial removal. 37° C. Red colonies.	Per cent positive with test for B. coli. Untreated effluent.	Per cent positive with test for B. coli. Treated effluent.
1906.				*Galls.*	*Galls.*	*Galls.*	°*C.*	°*C.*																		*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
Nov. 16	8.8	6.4	7.8	102,000	80,000	88,000	8.3	10.0	11	8	22	22	16	4.4	5.0	0.30	5.0	74	31	64,000	48,000	6,750	1,300	859	131	25	81	85	50	33
19	7.5	2.4	4.2	363,000	118,000	209,000	8.0	9.3	25	22	10	15	18	5.3	2.5	.30	25.0	64	23	130,000	26,500	14,800	5,400	936	95	80	64	90	33	28
20	8.9	6.0	7.0	220,000	151,000	189,000	21.6	12.5	27	21	16	30								78,000	11,000	14,000	700	50	1	86	95	98	60	0
21	14.0	13.0	14.0	138,000	126,000	129,000	23.0	13.5	16	13	18	18	16	4.7	2.3	.50	25.0	60	22	75,000	9,600	15,500	600	75	0	88	97	100	33	0
22	25.0	21.0	22.0	126,000	118,000	122,000	4.4	11.0	6	7	11	15	13	3.6	5.0	.24	25.0	71	31	55,000	6,800	5,700	200	95	0	88	97	100	54	0
27	11.0	7.5	9.1	118,000	80,000	96,000	5.5	9.0	17	10	17	18	31	2.0	5.0	.05	17.0	62	20	225,000	28,000	21,000	1,600	890	5	88	93	99	80	57
Dec. 4	9.4	8.3	8.3	80,000	70,000	80,000	2.5	6.0	11	11	18	17	21	6.5	2.5	.30	5.0	85	52	70,000	3,800	5,300	180	310	8	95	97	98	....	14

A duplicate test was carried through a few months later, when the temperature was much lower. The effluent was somewhat better organically, however, perhaps offsetting the effect of the lower temperature, and the bacterial removal was only slightly reduced, as is shown in Table IIIa.

TABLE IIIa.—*Volume of flow, temperature, organic and suspended matters, and efficiency of copper sulphate applied to effluent, Boys' Industrial School, Lancaster, Ohio.*

Date.	Copper sulphate, parts per million.			Volume of effluent treated.			Temperature.		Parts per million.													Bacteria per cubic centimeter.						Bacterial removal.			Per cent positive with test for *B. coli*.	
										Nitrogen as—				Suspended matter.		Carbonic acid.						20° C.		37° C.					37° C.			
																Free.		Half bound.						Total count.		Red colonies.						
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.	Oxygen consumed.	Organic.	Free ammonia.	Nitrites.	Nitrates.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Dissolved oxygen.	Putrescibility.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	20° C.	Total colonies.	Acid colonies.	Untreated effluent.	Treated effluent.
1907.				*Galls.*	*Galls.*	*Galls.*	° *C.*	° *C.*																				*P. c.*	*P. c.*	*P. c.*	*P. c.*	*P. c.*
Jan. 29	10	7.9	8.5	191,000	150,800	177,000	−0.5	4.0	11	0.7	3.6	0.36	2.0	37	33	14	13	22	22	6.8	0	49,000	5,400	8,800	1,300	250	100	89	85	60	75	25
30	13	12	13	177,800	150,800	158,000	−2.0	4.0	13	1.6	4.0	1.20	2.0	18	18	14	13	21	21	....	0	58,000	5,300	9,000	300	600	1	91	97	99.9	57	25
31	6.6	4.9	5.8	204,300	150,800	171,400	0.0	4.0	14	1.2	4.0	1.20	2.0	14	13	14	13	22	21	....	0	82,000	8,000	12,000	565	260	45	88	95	83	60	....

The daily application of copper sulphate to the Lancaster sand filter effluent with its flow of 160,000 gallons a day would require 17.3 pounds of copper sulphate, and the cost of this chemical would be about $1.04 a day, based on applying 13 parts of copper sulphate to each million gallons of effluent.

The cost of constructing the Lancaster plant used in these experiments and capable of treating sewage at the rate of 160,000 gallons for six hours was $29. However, a fair estimate of the cost of a plant under practical conditions for continuous treatment would be about $92, proportioned as follows:

2 solution-tanks, 1,400 gallons capacity	$45.00
Orifice box	8.75
Brass orifice	2.00
Float control	1.25
Pipe	5.00
Lumber	5.00
Labor	25.00
Total	92.00

The maintenance cost per annum on the above basis would be as follows:

6,325 pounds of copper sulphate, at 6 cents a pound	$379.50
Labor, 365 days, at $2 a day	730.00
Total	1,109.50

Capitalized at 5 per cent, this would represent an investment of $22,000.

MARION.

The sewage disposal plant at Marion, Ohio, has been described in detail,[a] and it is necessary here only to refer to the plant as a combination of septic tanks, contact filters, and sand filters, handling about 600,000 gallons of sewage daily.

To provide a storage reservoir for the copper-sulphate-treated sewage a dam was built in the effluent sewer about 900 feet west of the disposal plant and a cofferdam composed of 6-inch sheathing was constructed at the outlet of the effluent sewer into Rock Swale Creek. The exposed height of the sheathing was such that in all but extreme flood stages the effluent would discharge into the creek in a clear sheet. The object of thus protecting the outlet of the effluent sewer was to overcome possible outside contamination of the copper-treated effluent due to backwater from the creek, which quite probably receives considerable quantities of domestic sewage. During

[a] Pratt, R. Winthrop. Combined Septic Tanks, Contact Beds, Intermittent Filters and Garbage Crematory, Marion, Ohio. Engineering News, vol. 55, No. 8, pp. 197–201, 5 figs. New York, February 22, 1906.

the experiments the waters of the creek rose so as completely to overflow the cofferdam, but on such days no tests were made. In all of the runs it was possible to collect samples of the effluent as discharged without danger of contamination from the waters of the creek. The storage or contact period of sewage effluent and copper sulphate was determined to be about one hour. The copper-sulphate solution, prepared in a solution tank of 1,780 gallons capacity, was discharged at the rate of 2 gallons a minute.

At the present time the disposal plant is hand operated in the daytime only; during the night the contact filters are operated continuously. Beginning at about 7 o'clock a. m. and continuing until about 5 p. m. the normal hand operation of the plant is resumed and it was during such normal operation that the copper experiments were carried out. From 7 o'clock a. m. until 10 a. m. practically no water is discharged into the effluent channel; hence all of the tests began at about 10 a. m. Samples were collected at half-hourly intervals, an allowance being made for the storage period of one hour.

The results of these experiments, shown in detail in Table IV, are somewhat disappointing. The degree of bacterial purification did not equal that obtained at Westerville and, as at Westerville, a great increase in the quantity of copper sulphate applied caused but slightly increased efficiency. The chemical condition of the effluent at Marion was somewhat similar to that at Westerville, but the time of contact with copper sulphate was much shorter. As several investigators[a] have shown, time of contact is a very important element in the germicidal action of copper, and the low bacterial removal is probably due to this factor.

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[a] Gildersleeve. Studies on the Bactericidal Action of Copper on Organisms in Water. American Journal of Medical Science, n. s., vol. 129, No. 5, pp. 754–760. Philadelphia and New York, May, 1905.

Johnson, George A. Report on Sewage Purification at Columbus, Ohio, 1905.

Kraemer, Henry. Copper Treatment of Water. American Journal of Pharmacy, vol. 16, No. 12, pp. 574–579. Philadelphia, December, 1904.

Phelps, E. B. Experiments on the Storage of Typhoid-Infected Water in Copper Canteens. American Public Health Association, Report, vol. 31, part 1, pp. 75–90. 1905.

Moore, G. T., and Kellerman, K. F. Method of Destroying or Preventing the Growth of Algæ and Certain Pathogenic Bacteria in Water Supplies. Bul. 64, Bureau of Plant Industry. 1904. Copper as an Algicide and Disinfectant in Water Supplies. Bul. 76, Bureau of Plant Industry. 1905.

Kellerman, K. F., and Beckwith, T. D. The Effect of Copper upon Water Bacteria. Bul. 100, Pt. VII, Bureau of Plant Industry, pp. 57–71. 1907.

TABLE IV.—*Volume of flow, temperature, organic and suspended matters, and efficiency of copper sulphate applied to effluent, Marion, Ohio.*

Date.	Copper sulphate, parts per million.			Volume of effluent treated.			Temperature.		Parts per million.												Putrescibility.	Bacteria per cubic centimeter.						Bacterial removal.			Per cent positive with test for *B. coli*.	
									Oxygen consumed.	Nitrogen as—				Suspended matter.		Carbonic acid.				Dissolved oxygen.		20° C.		37° C.					37° C.			
																Free.		Half bound.						Total count.		Red colonies.						
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.		Organic.	Free ammonia.	Nitrites.	Nitrates.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.			Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	20° C.	Total colonies.	Acid colonies.	Untreated effluent.	Treated effluent.
				Galls.	*Galls.*	*Galls.*	°*C.*	°*C.*																				*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1906.																																
Dec. 19	5	3	3	732,000	391,000	640,000	3.1	6.0	12	2.3	5.6	0.22	4.4	21	10	21	21	142	140	6.5	0	290,000	67,000	93,000	44,000	1,200	1,300	77	53	−8	38	63
20	9	4	6	596,000	284,000	469,000	3.0	8.2	9	7.3	4.6	.18	0.0	29	13	17	17	142	142	4.0	0	400,000	78,000	390,000	59,000	3,200	1,200	80	85	62	29	50
27	16	5	7	779,000	249,000	553,000	1.5	5.5	17	9.9	6.0	.15	4.4	22	11	26	24	143	143	4.7	0	410,000	170,000	75,000	36,000	12,000	4,300	58	52	63	.....	44
28	22	7	10	732,000	217,000	553,000	3.6	7.5	14	2.3	5.6	.20	5.0	23	10	36	35	139	139	4.0	0	450,000	125,000	140,000	25,000	16,000	4,800	72	82	70	.....	44
1907.																																
Jan. 2	36	10	13	829,000	217,000	596,000	6.0	8.3	15	2.1	5.0	.50	6.0	21	12	26	26	128	128	6.8	0	380,000	97,000	58,000	19,000	6,000	2,500	74	67	60	.....	78
7	27	12	17	926,000	427,000	686,000	15.0	10.0	10	6.3	0.0	.80	6.0	23	11	25	25	110	110	6.8	0	84,000	33,000	26,000	12,000	4,000	1,800	61	54	55	.....	67
9	37	27	32	985,000	732,000	829,000	4.7	7.7	10	3.1	4.0	.84	3.0	39	16	16	16	114	114	6.4	0	22,000	5,400	38,000	13,000	5,000	1,000	75	67	80	.....	33
10	53	40	48	985,000	779,000	829,000	.8	7.0	10	2.3	4.0	.90	6.0	29	10	17	17	128	128	5.9	0	36,000	7,500	21,000	4,000	5,500	450	78	81	92	.....	53
14	154	110	116	732,000	525,000	689,000	9.8	9.5	10	1.9	3.6	.40	4.0	24	11	27	26	123	123	6.1	0	84,000	7,000	28,000	2,000	5,000	560	92	93	89	.....	31

The application of copper sulphate to the Marion sand-filter effluent with a daily flow of 600,000 gallons on a basis of applying 20 parts of copper sulphate to each million gallons of effluent would cost $6 a day for chemicals, and the cost of constructing a plant for applying the copper sulphate would be about $151, the main items being as follows:

3 1,500-gallon solution tanks	$99.00
Pipe and lumber	20.00
Orifice box and float control	10.00
Brass orifice	2.00
Labor	20.00
Total	151.00

The cost of treatment annually on the above basis—that is, using copper sulphate to the extent of 20 parts to the million—would be about $2,920, proportioned as follows:

36,500 pounds of copper sulphate, at 6 cents a pound	$2,190.00
Labor, one man, 365 days, at $2 a day	730.00
Total	2,920.00

Capitalized at 5 per cent this would represent an investment of $58,000.

CHLORIN EXPERIMENTS.

After completing the experiments with copper sulphate it was decided to discontinue the copper work and experiment with the use of chlorin in the disinfection of sewage effluents of different degrees of purity. The use of hypochlorites or electrolytic chlorin has been studied for some years and processes based upon the use of chlorin have been installed for sewage treatment at some places. Unfortunately these processes usually were expected to purify as well as disinfect sewage and necessarily were unsuccessful. It is true that in the case of certain hospitals it may be desirable to disinfect the crude sewage discharged from them and this may be done satisfactorily by means of chlorin[a] without interfering with the subsequent biological phenomena of purification.[b] Generally speaking, however, the proper function of germicides in dealing with a large quantity of sewage is that of improving the biological character of the previously chemically purified effluent. This chemical purifica-

[a] Schumacher. Die Desinfektion von Krankenhausgruben mit besonderer Berück-sichtigung des Chlorkalkes und ihre Kontrolle. Gesundheits-Ingenieur, 28th year, No. 22, pp. 361–368, August 10; No. 23, pp. 376–384, August 19; No. 24, pp. 393–397 August 30. Munich, 1905.

[b] Dunbar and Korn. Zur Desinfektion von Abwässern mit gleichzeitiger Reinigung derselben. Gesundheits-Ingenieur, 27th year, No. 2, pp. 17–20. Munich, January 20, 1904.

tion may be only partial, as in the case of the effluent from septic tanks,[a] or complete, as in the case of a high-grade sand-filter effluent. This phase of the subject has recently attracted considerable attention, due perhaps to the advocacy of the use of chlorin for preventing the dangerous sewage contamination of shellfish beds.[b]

Our first experiments to determine the efficiency of chlorin as a germicide were made at Lancaster, together with a few laboratory experiments in regard to chlorin absorption by the organic matter in the effluent under treatment and in artificial mixtures containing different amounts of crude organic matter. Similar and more exhaustive experiments were conducted at Marion.

As the most inexpensive and practical source of chlorin for the experiments in question, calcium hypochlorite, or bleaching powder, was selected. This commercial product will cost, upon an average, about 3 cents a pound, and in large quantities may be purchased for 2½ or 2¾ cents a pound. The strength of the commercial chlorid of lime in bulk varies widely and according to analyses of the commercial product purchased in Columbus, Ohio, ranges from 18 to 25 per cent of available chlorin, depending largely upon the degree of exposure to which it has been subjected. As an average cost figure it may be stated that commercial chlorid of lime packed in large air-tight drums and guaranteed to contain 25 per cent of available chlorin may be purchased in Ohio for 2½ cents a pound. On this basis the data of cost have been calculated.[c]

For the sake of convenience and accuracy in our experimental work, it was decided to take advantage of a product placed on the market in 10-pound sealed containers, costing 4 cents a pound and showing on analysis 34 per cent of available chlorin. This product, of course, was more uniform than the cheaper product purchased in bulk and, moreover, was not liable to decreasing chlorin content due to exposure.

According to the experience gained at Lancaster and Marion, the preparation of the hypochlorite solution is an important feature in

[a] Indian Government. Resolutions on the Working of Septic Tanks. Calcutta, January 6, 1906.

[b] Digby, W. Pollard, and Shenton, Henry C. H. Prevention of the Bacterial Contamination of Streams and Oyster Beds. London, published by the Society of Engineers, 1906.

Phelps, E. B., and Carpenter, W. T. The Sterilization of Sewage Filter Effluents. Technology Quarterly, vol. 19, No. 47, pp. 382–403. Boston, December, 1906.

Phelps, E. B. The Sterilization of Sewage Filter Effluents. Science, vol. 25, No. 647, pp. 808–809. Garrison, N. Y., May 24, 1907.

Kershaw, John B. C. Electrolytic Methods of Sewage Sterilization. Surveyor and Municipal and County Engineer, vol. 30, pp. 662 664, 749–750. London, 1905.

[c] In some localities bleaching powder in sealed containers can be purchased at from 1½ to 2 cents a pound.

the successful chlorin treatment of sewage effluents. It was found that unless special precautions are taken in dissolving the bleaching powder, many large lumps which inclose chlorin remain and materially reduce the efficiency of a given weight of bleaching powder.

The method of preparation found by our experience to give the best results is as follows: A weighed quantity of bleaching powder is placed in a shallow box and covered with sufficient water to form a smooth paste. More water is then added until the heavier particles settle out, thus allowing the soluble and finely divided chlorid of lime to be decanted. After decantation more water is added, the coarse lumps are broken up, and the process repeated until as much as possible has gone into solution. The importance of thoroughly mixing the chlorid of lime solution and of grinding the dried chlorid as finely as possible can not be too strongly emphasized; otherwise a loss of from 10 to 30 per cent may take place, especially in the case of low-grade bleaching powder. Experiments with a high-grade bleaching powder of known strength indicate that the loss of chlorin when the above precautions are taken is not more than 1 per cent.

BOYS' INDUSTRIAL SCHOOL, LANCASTER.

The leading results obtained during the first series of chlorin tests carried out at Lancaster are listed in Table V, from which it appears that none of the samples of treated effluent examined contained acid-forming colonies; the removal of coli-like organisms was therefore practically 100 per cent. On each day six samples were collected and were plated in duplicate upon lactose-azolitmin agar, so that the results represent averages of 36 samples with 1 cubic centimeter examined in each case.

Accompanying the complete removal of coli-like organisms, the treatment with chlorin in amounts as indicated effected a removal of total organisms of 99.8, 99.9, and 99.9 per cent, respectively. In organic compounds the effluent under treatment was substantially similar to that found during the copper experiments, and the temperature of the effluent was practically at the maximum density of 4° C. In reviewing the results it is interesting to note the increase in dissolved oxygen, presumably arising from the liberation of oxygen from the calcium hypochlorite. It should be noted further that in practically all instances by means of the iodo-starch tests residual chlorin was detected at the discharge weir after a storage of about three hours. The hypochlorite solution was tested twice during a six-hour run, but in that time was found to be almost constant. This solution was discharged into the sewage effluent at the rate of 0.75 gallon a minute, and variations in the quantity of chlorin applied were made by changing the strength of the hypochlorite solution.

TABLE V.—*Volume of flow, temperature, organic and suspended matters, and efficiency of calcium hypochlorite applied to effluent, Lancaster, Ohio.*

Date.	Available chlorin. Parts per million.			Volume of effluent treated.			Temperature.	
	Maximum	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.
1907.				*Gallons.*	*Gallons.*	*Gallons.*	°*C.*	°*C.*
Feb. 8	4.0	3.2	3.6	234,800	191,000	208,200	2.0	4.0
13	6.3	4.0	4.3	191,000	117,800	174,600	11.0	4.0
15	4.1	3.7	4.0	102,000	91,200	94,800	.5	5.0

Date.	Parts per million.																	
	Oxygen consumed.		Nitrogen as—								Suspended matter.		Carbonic acid.				Dissolved oxygen.	
			Organic.		Free ammonia.		Nitrites.		Nitrates.				Free.		Half bound.			
	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.
1907.																		
Feb. 8	15	13	1.9	....	6.0	5.0	1.20	0.70	2.0	3.0	5	0	20	16	22	21	9.8	11.5
13	16	24	1.7	....	11.0	10.0	1.80	0.90	3.0	3.0	5	0	24	15	33	21	9.6	11.6
15	15	15	.....	....	10.0	8.0	1.60	1.40	3.6	3.0	16	0	30	20	30	27	8.8	7.3

Date.	Putrescibility.	Bacteria per cubic centimeter.						Bacterial removal.			Per cent positive with test for *B. coli*.	
		20° C.		37° C.				20° C.	37° C.			
				Total count.		Red colonies.						
		Untreated effluent.	Treated effluent.	Untreated effluent	Treated effluent.	Untreated effluent.	Treated effluent.		Total colonies.	Acid colonies.	Untreated effluent.	Treated effluent.
1907.								*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Feb. 8	0	100,000	150	15,000	48	140	0	99.8	99.7	100	43	....
13	0	105,000	120	11,000	45	1,500	0	99.9	99.6	100	66	....
15	0	192,500	140	15,000	55	870	0	99.9	99.6	100	60	....

The cost of constructing a plant for treating the sand filter effluent of the Boys' Industrial School with chlorin may be taken at $92. Substantially the same plant could be used as in the case of treatment with copper sulphate.

The estimates upon the cost of chemicals are based upon bleaching powder containing 25 per cent of available chlorin and costing 2½ cents a pound. The annual cost, applying 4 parts to the million of available chlorin to a sand filter effluent flow of 160,000 gallons, would be about $924, including labor, proportioned as follows:

7,770 pounds of bleaching powder, at 2½ cents a pound.........	$194.25
Labor, 1 man, 365 days, at $2 a day........................	730.00
Total..	924.25

Capitalized at 5 per cent, this would represent an investment of $18,500.

MARION.

The procedure adopted in the chlorin disinfection tests was substantially similar to that followed in the experiments with copper sulphate, but the rate of application of the disinfectant solution was increased to 3 gallons a minute. As the effluents from either the septic tanks or the contact filters could be diverted directly into the effluent sewer, experiments were planned with each of the three grades of sewage effluents—from the sand filters, from the contact filters, and from the septic tanks.

The effluent from the sand filters was first experimented with, and the quantity of chlorin applied during the three runs on the sand filter effluent was on the average 3.8, 3.0, and 1.5 parts to the million. An examination of the tabulated chemical data given in Table VI will show interesting indications as to the effect of the applied chlorin on the character of the treated effluent, pointing to a considerable reduction in free carbonic acid and to an increase in the quantity of dissolved oxygen. The change in the nitrates and nitrites in the case of these three runs is apparently too small to warrant discussion. As shown in Table VI, in the first two runs the sterilizing effect of the chlorin was sufficient to remove 98.8 and 99.7 per cent of the total bacteria, 98.5 and 99.1 per cent of bacteria developing on lactose-azolitmin agar at 37° C., and 100 per cent of the acid-forming bacteria, respectively. The conclusion may therefore be drawn that *Bacillus coli* was not present in the treated effluent. On the third test with a chlorin concentration on the average of only 1.5 parts to the million, the bacterial removals were 94.3 for total bacteria at 20° C., 99.2 for bacteria developing on lactose-azolitmin agar at 37° C., and 99.9 per cent for acid-forming bacteria. The average of the platings at 37° C. in the case of the third run contained but one red colony. This, by full determinative tests, was found to be *Bacillus coli.*

TABLE VI.—*Volume of flow, temperature, organic and suspended matter, and efficiency of calcium hypochlorite applied to sand and contact filter effluents and to septic sewage, respectively, Marion, Ohio.*

Date.	Source.	Available chlorin. Parts per million.			Volume of effluent treated.			Air.	Effluent.
		Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.		
1907.					*Gallons.*	*Gallons.*	*Gallons.*	*°C.*	*°C.*
Mar. 21	Sand effluent........	4.9	3.3	3.8	779,000	525,000	686,000	19.0	9.2
22	Sand effluent........	4.1	2.2	3.0	876,000	469,000	640,000	26.0	11.3
26	Sand effluent........	2.8	.96	1.5	829,000	284,000	525,000	25.0	12.0
28	Contact effluent.....	14.5	1.7	2.9	1,313,000	156,000	779,000	19.0	11.5
29	Contact effluent.....	20.4	2.6	5.03	1,446,000	186,000	755,000	21.5	11.5
Apr. 3	Contact effluent.....	31.8	2.0	4.4	1,143,000	77,000	539,000	19.0	10.6
11	Septic effluent.......	4.3	3.7	4.3	686,000	596,000	596,000	2.5	10.5
12	Septic effluent.......	6.2	5.8	6.2	640,000	596,000	596,000	3.0	11.0
15	Septic effluent.......	8.2	7.0	7.6	640,000	553,000	596,000	8.0	5.6

TABLE VI.—*Volume of flow, temperature, organic and suspended matter, and efficiency of calcium hypochlorite applied to sand and contact filter effluents and to septic sewage, respectively, Marion, Ohio*—Continued.

Date.	Source.	Parts per million. Oxygen consumed.		Nitrogen as— Organic.		Free ammonia.		Nitrites.		Nitrates.		Suspended matter.		Carbonic acid. Free.		Half bound.		Dissolved oxygen.	
		Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.
1907.																			
Mar. 21	Sand effluent..	17	16	3.3	....	0.6	0.7	1.70	1.60	12.0	12.0	2	...	28	21	116	115	4.8	5.8
22	Sand effluent..	16	15	3.2	....	0.7	0.8	1.60	1.60	11.0	11.0	2	...	36	26	132	129	5.0	5.5
26	Sand effluent..	17	17	3.9	....	2.0	1.6	0.60	0.80	9.0	8.6	3	...	34	26	163	163	5.9	7.2
28	Contact effluent........	12	12	0.9	....	7.0	7.0	0.56	1.20	10.4	9.6	5	...	19	15	176	163	0.0	0.0
29	Contact effluent........	15	12	1.3	....	6.6	6.6	0.80	0.60	7.0	6.0	4	...	25	24	185	180	3.1	4.0
Apr. 3	Contact effluent........	26	23	3.6	....	6.0	9.0	0.20	0.19	3.0	1.6	8	...	42	39	176	176	1.5	5.4
11	Septic effluent.	40	42	14.2	....	20.0	20.0	0.06	0.00	0.0	0.2	34	28	25	15	....	....	0.3	2.8
12	Septic effluent.	50	48	14.2	....	20.0	22.0	0.30	0.20	0.0	0.0	32	27	39	20	....	....	1.7	3.0
15	Septic effluent.	48	....	14.0	....	35.0	30.0	0.00	0.00	0.0	0.0	36	30	56	41	250	....	0.0	0.0

Date.	Source.	Putrescibility.	Bacteria per cubic centimeter. 20° C.		37° C. Total count.		Red colonies.		Bacterial removal. 20° C.	37° C. Total colonies.	Acid colonies.	*B. coli* per cubic centimeter. Untreated effluent.	Treated effluent.
			Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.					
1907.									*P. ct.*	*P. ct.*	*P. ct.*		
Mar. 21	Sand effluent.	0	49,000	570	9,800	150	1,300	0	98.8	98.5	100	1,000	Not in 1 c.c.
22	Sand effluent.	0	56,000	140	7,000	60	800	0	99.7	99.1	100	2,000	Not in 1 c.c.
26	Sand effluent.	0	70,000	4,000	20,000	160	4,000	1	94.3	99.2	99.9	2,000	Present in 1 c.c.
28	Contact effluent	0	110,000	2,500	....	....	....	......	97.8	.....	.....	20,000	Not in 0.5 c.c.
29	Contact effluent.	+	65,000	1,600	73,000	370	10,000	0	97.6	99.5	100	15,000	Not in 0.5 c.c.
Apr. 3	Contact effluent.	+	500,000	800	160,000	400	21,000	3	99.8	99.4	99.9	20,000	Not in 1 c.c.
11	Septic effluent.	+	850,000	1,100,000	1,200,000	240,000	55,000	7,400	— 130	80.0	87.0	......	....
12	Septic effluent.	+	4,400,000	550,000	850,000	260,000	60,000	15,000	88.0	70.0	75.0	......	....
15	Septic effluent.	+	600,000	400,000	450,000	190,000	100,000	51,000	36.0	50.0	49.0	......	....

In addition to the enumeration of the acid-forming colonies already mentioned, further data were obtained as to the colon content of the treated effluent by means of the dilution method, using

fermentation tubes, supplemented by determinative tests. This method applied to the untreated effluent in the case of the three runs under discussion indicated the range of *Bacillus coli* as 1,000, 2,000, and 2,000 to the cubic centimeter, respectively. In the case of the treated effluent, however, the organisms were not found in 1 cubic centimeter. In the third run, however, with a chlorin concentration of only 1.5 parts to the million, the presence of *Bacillus coli* was detected in 1 cubic centimeter. At fifteen-minute intervals during these tests the presence of residual chlorin was determined at the weir in the effluent sewer and at the outlet into Rock Swale Creek. The results of these tests in the case of the sand-filter effluent were always negative.

The effluent from the contact filters was now diverted directly to the treating chamber. This effluent, of course, contained organic matter of a more putrescible character than did the sand effluent previously studied. The quantity of chlorin applied ranged from a minimum of 1.7 to a maximum of 14.5 on the first run; on the second run from a minimum of 2.6 to a maximum of 20.4; and on the third run a minimum of 2 to a maximum of 31.8 parts to the million. The quantity of sewage discharged varied widely at different times during the day, depending upon the amount of sewage held in the filter. At the end of a discharge the rate is very small, and during such periods, of course, the strength of chlorin applied was greatly increased.

In this connection, the following tabulation of weir readings of one run with the contact-filter effluent will be of interest as illustrating the fluctuation in the quantity of effluent to be treated. In a case of this sort it is necessary to apply chlorin sufficient to disinfect the maximum rate of flow, but where possible storage facilities should be provided to impound the effluent and thus secure a discharge at a regular rate.

TABLE VII.—*Different rates of flow of contact-filter effluent, Marion, Ohio, March 28, 1907, computed on the basis of a twenty-four-hour constant flow.*

Time of measurements.	Gallons to the twenty-four hours.	Time of measurements.	Gallons to the twenty-four hours.	Time of measurements.	Gallons to the twenty-four hours.
10.30 a. m.	1,312,800	12.15 p. m.	525,100	2.00 p. m.	469,000
10.45 a. m.	1,312,800	12.30 p. m.	778,800	2.15 p. m.	1,253,800
11.00 a. m.	316,000	12.45 p. m.	828,900	2.30 p. m.	828,900
11.15 a. m.	1,085,600	1.00 p. m.	926,300	2.45 p. m.	155,500
11.30 a. m.	685,900	1.15 p. m.	778,800	3.00 p. m.	1,085,600
11.45 a. m.	1,444,800	1.30 p. m.	216,500	3.15 p. m.	525,100
12.00 a. m.	926,300	1.45 p. m.	876,200	3.30 p. m.	1,032,500

The effect of the applied chlorin on the chemical character of the contact-filter effluent is similar to that produced in the sand-filter effluents with the exception that the nitrites in the treated effluent

were considerably higher than in the effluent before chlorin treatment. The average quantity of chlorin, 2.9 parts to the million, sufficed to remove 97.8 per cent of the total organisms. The tests for *Bacillus coli* by the dilution method indicated that the contact-filter effluent contained about 20,000 to the cubic centimeter, but after treatment these organisms usually could not be detected in 0.5 cubic centimeter of the effluent.

In the second run, with an average chlorin application of 5 parts to the million, the reduction of total organisms was 97.6 per cent, that of bacteria developing at 37° C. on lactose-azolitmin agar was 99.5 per cent, and the removal of acid-forming bacteria was 100 per cent. Further, *Bacillus coli* usually was not found in 0.5 cubic centimeter of the treated effluent, while in the untreated effluent it was found in numbers averaging 15,000 to the cubic centimeter. The total organisms in the treated effluent were 1,600, and the total development at 37° C. was 370 to the cubic centimeter. No red colonies were found during this run.

On the third run, with an average chlorin application of 4.4 parts to the million, the total removal of bacteria developing at 20° C. was 99.8 per cent, the removal of bacteria developing at 37° C. was 99.4 per cent, and the removal of acid-forming bacteria was 99.9 per cent. The red colonies developing in the case of the untreated effluent contained 21,000 organisms to the cubic centimeter, while in the treated effluent only 3 were found. The tests by the dilution method, however, indicated that *Bacillus coli* usually was not present in 1 cubic centimeter, although found in the untreated effluent approximately 20,000 to the cubic centimeter.

The tests for residual chlorin in the treated effluent at the manhole in the effluent sewer and at the cofferdam were always negative at the latter point, although occasionally positive at the former. The details of these experiments are shown in Table VI.

Following the experiments with the treatment of the contact filter effluent, attention was directed to the application of chlorin to the effluent from the septic tanks. The addition of approximately 5 parts of chlorin to 1,000,000 parts of septic sewage did not suffice to effect a very material removal of either total bacteria or fermenting organisms. The data given in Table VI show a total bacterial removal ranging from 36 to 88 per cent. A higher concentration of chlorin produced only a slight increase in efficiency. At the highest concentration tested, the acid-forming bacteria in the applied sewage were 100,000 to the cubic centimeter and were reduced by the chlorin treatment to 51,000, showing an average reduction of 49 per cent. The indications from the experiments in the chlorin treatment of the septic effluent are that with the quantity of chlorin applied ranging from 4.3 to 7.6 parts to the million the removal of bacteria is by no

means as complete as is desirable. Tests for the presence of residual chlorin in the treated effluent were carried out, but were negative in every instance.

Following the experiments just discussed, in which the quantity of chlorin applied ranged from 4.3 to a maximum of 7.6 parts to the million, an effort was made to learn the efficiency of greatly increased amounts of chlorin. Such information would appear to be of considerable importance in connection with the disinfection of hospital sewages at times of epidemics in cases where sedimentation alone is the only permanently available means of treating the crude sewage. To this end six experiments in the chlorin treatment of septic sewage were made at Marion, the amount of chemical applied ranging from an average of 7.3 to a maximum average of 48.5 parts to the million. The experiments at these higher concentrations were conducted substantially as those already discussed.

By reference to Table VIII it will be noted that about 25 parts to the million of applied available chlorin were sufficient to remove a substantial proportion of coli-like organisms, although a complete removal of *Bacillus coli* was not accomplished. In the case of the fourth experiment at an approximate concentration of 25 parts to the million, with a sewage flow averaging about 650,000 gallons, the total bacteria in the untreated sewage averaged 800,000 and were reduced to 62,000. The number of bacteria to the cubic centimeter developing on lactose-azolitmin agar at 37° C. was 200,000 and was reduced to 35,000. *Bacillus coli* in this test, as shown by the bile broth fermentation tube method,[a] was present in numbers amounting to 15,000 to the cubic centimeter in the untreated sewage and 50 to the cubic centimeter after chlorin treatment, the reduction being 99.3 per cent.

In the subsequent runs in which the concentration of the applied available chlorin was increased to a maximum average of 48.5 parts to the million the removal of *Bacillus coli* was found only slightly greater than in the case of the application of 25 parts to the million of available chlorin, the number of *Bacillus coli* remaining in the treated sewage ranging from 20 to 200 to the cubic centimeter. In this connection it should be noted that the suspended matter in the septic effluent increased considerably, and this probably in large part explains the low removals obtained with the increased quantity of applied chemical. Observations made during the experiments at Marion emphasize the great effect of the periodic discharge of a septic effluent charged heavily with suspended matters. At such times, no doubt, the absorption of the chlorin is very great, and presumably the

[a] Jackson, D. D. "A new solution for the presumptive test for Bacillus coli." Biological Studies by the Pupils of William Thompson Sedgwick, pp. 292–299. Boston, 1906.

organic matters in suspension in the septic effluent destroy a considerable part of the disinfectant added.

The effect of the different concentrations of applied chlorin in the case of the Marion septic sewage is noticeably erratic in this regard. The conclusion seems tenable that these irregularities are, in great part at least, to be attributed to the presence in the septic effluent of large masses of suspended matter. On this account available evidence seems to point to the strong advisability of thoroughly settling a septic tank effluent in the case of contemplated chlorin treatment, except, of course, in those special cases where the flexibility of the design of the septic tanks is such that a well-settled septic effluent is normally obtained at all times.

TABLE VIII.—*Volume of flow, temperature, organic and suspended matter, and efficiency of calcium hypochlorite applied to septic sewage, Marion, Ohio.*

Date.	Available chlorin (parts per million).			Volume of effluent treated.			Temperature.	
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.
1907.				*Gallons.*	*Gallons.*	*Gallons.*	*°C.*	*°C.*
May 3	7.5	7.0	7.3	779,000	732,000	755,000	16.0	10.5
6	19.6	17.03	18.3	779,000	676,000	709,000	11.0	10.5
10	23.6	22.2	22.9	779,000	732,000	732,000	13.5	10.5
13	27.3	22.2	24.8	732,000	596,000	647,000	27.0	11.0
15	34.6	27.2	30.6	779,000	640,000	698,000	15.5	11.5
17	52.1	44.8	48.5	640,000	553,000	600,000	22.0	11.5

Parts per million.

Date.	Oxygen consumed.	Nitrogen as—							Suspended matter.		Carbonic acid.				Dissolved oxygen.	
			Free ammonia.		Nitrites.		Nitrates.				Free.		Half bound.			
		Organic.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.
1907.																
May 3	46	8.0	16.0	16.0	0.50	0.50	0.0	0.0	44	34	59	46	181	181	0.0	2.8
6	51	7.6	18.0	20.0	0.00	0.10	0.0	0.0	47	37	51	43	180	176	0.0	3.1
10	36	6.0	14.0	12.0	0.60	0.50	0.0	0.0	30	14	60	44	171	167	1.2	4.8
13	29	4.0	20.0	16.0	0.20	0.20	0.0	0.0	104	86	62	38	184	183	0.0	3.9
15	42	5.6	20.0	20.0	0.00	0.00	0.0	0.0	77	63	53	39	188	186	0.0	2.3
17	43	4.0	20.0	20.0	0.00	0.06	0.0	0.0	79	69	60	35	197	194	0.0	3.4

Date.	Putrescibility.	Bacteria per cubic centimeter.						*B. coli* per cubic centimeter, bile medium.		Bacterial removal.			
		20° C.		37° C.							37° C.		
				Total count.		Red colonies.							
		Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	20° C.	Total colonies.	Acid colonies.	*B. coli*, by bile.
1907.										*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
May 3	+	250,000	290,000	1,000,000	470,000	55,000	35,000	....	....	−16	53	36	.....
6	+	1,200,000	950,000	850,000	360,000	45,000	28,000	50,000	10,000	20.0	57.6	38	80.0
10	+	1,700,000	2,500	120,000	800	50,000	0	30,000	100	99.8	99.3	100	99.3
13	+	800,000	62,000	200,000	35,000	48,000	....	15,000	50	92.2	82.5	.....	99.3
15	+	750,000	290,000	....	....	....	....	30,000	150	61.3	.....	.....	99.5
17	+	750,000	72,000	....	....	....	....	30,000	35	90.4	.....	.....	99.8

The cost of constructing a plant for treating the several effluents studied at the Marion sewage plant may be taken as $151, exclusive of arrangements for supplying water to dissolve the chlorid of lime. This estimate allows for continuous treatment at a rate of flow of 600,000 gallons in twenty-four hours.

The cost of applying 4 parts to the million of available chlorin to the sand filter effluent is $730 annually. The total annual cost, including labor but excluding the cost of supplying water for preparing the chlorin solution, would be about $1,620 on the basis of an effluent flow of 600,000 gallons daily. Capitalized at 5 per cent, this would represent an investment of $29,000.

The cost of applying 5 parts to the million of available chlorin to the contact filter effluent would be about $2.50 a day, requiring 100 pounds of the chemical. The total annual cost, including labor but excluding the cost of pumping or otherwise supplying the water for dissolving the germicide, would be about $1,640. Capitalized at 5 per cent, this would represent an investment of $34,000.

Assuming 25 parts to the million as a fair average figure for the disinfection of the septic effluent, provided the same is at all times free from abnormal amounts of suspended matters, the total annual cost, including labor, would be about $5,300. Capitalized at 5 per cent, this would represent an investment of about $106,000.

CHLORIN ABSORPTION EXPERIMENTS.

In connection with studies made at Guilford, England, regarding the treatment of sewage effluents with chlorin, Doctor Rideal concluded that there was a fairly definite relation between the chlorin-consuming power of the effluent and the oxygen consumed resulting from a five-minute boiling test.[a] He states that the ratio of chlorin consumed to oxygen consumed is practically constant; that chlorin in excess of the absorption amount is required for sterilization, and that the quantity of chlorin necessary for treatment can be computed by multiplying the oxygen consumed by the factor 1.7.

In view of the importance attached to chlorin absorption by previous investigators and the fact that a fixed relation between the chlorin and the oxygen consumed, respectively, would be of marked value in the practical control of sterilization with chlorin, it was decided to make certain studies to inquire into the chlorin-oxygen relation for conditions at Lancaster, Ohio. Especially was this

[a] Rideal, Samuel. On the Sterilization of Effluents, etc. Journal of the Royal Sanitary Institute, vol. 26, No. 7, pp. 378–406; discussion, pp. 407–416. London, August, 1905. Oxychloride Sewage Purification. Sanitary Record and Journal of Sanitary and Municipal Engineering, vol. 34, pp. 329–332. London, October 6, 1904. Sewage and Bacterial Purification of Sewage. 3d ed., London and New York, 1906, p. 186.

important since a complete removal of *Bacillus coli* was obtained by the use of slightly less than 5 parts of chlorin to the million, and also since there was noted the presence of residual chlorin after a three-hour storage of the treated effluent. Taking into consideration the average oxygen consumed of the treated effluent, the indications were that the relation between the chlorin and the oxygen consumed was somewhat different from that suggested by Rideal.

Experiments at Lancaster bearing upon the supposed ratio between the chlorin and the oxygen consumed consisted in a series of tests in which various dilutions of crude sewage and of sewage-plant effluent were added to standard solutions of chlorin. The chlorin was, of course, added in the cold, and after a five-minute period of contact the residual chlorin was determined by titration with arsenious acid. A contact period of two hours was also studied to obtain information in regard to the effect of time on the absorption of the chlorin. To obtain the relation between the chlorin consumed and the oxygen consumed the latter was determined in the case of all samples by the standard method of boiling for exactly five minutes with an excess of permanganate in acid solution.

A second method of studying chlorin-absorption phenomena was carried out by adding to a known volume of the sewage effluent varying amounts of chlorin, ranging from 2 to 75 parts to the million. After the end of 0.25, 0.50, 0.75, 1.00, 1.50, 2.00, 2.50, 3.00, and 4.00 hours the presence of residual chlorin was determined by means of iodo-starch paper.

Speaking generally, the results of the experiments carried out at Lancaster as to chlorin consumed were somewhat erratic. In view of the high absorption, moreover, it is difficult to account for the presence of residual chlorin after three hours' storage when only 5 parts of chlorin to the million were being added to the sewage effluent, unless it is due to incomplete displacement in the storage reservoir. However this may be, the results at Lancaster indicated that there was no definite relation between the oxygen consumed and the chlorin consumed and that notwithstanding the high chlorin-absorptive capabilities of the sewage effluent the addition of 5 parts of chlorin to the million sufficed to destroy practically 100 per cent of the organisms of the colon group, indicating that oxygen liberated from the decomposing chlorid of lime accomplished disinfection, although the organic character of the effluent was such that it could absorb many times the quantity of chlorin applied. Referring to Tables IX to XI, inclusive, it will be noted that these results strongly indicate that there is no definite relation between the chlorin-consuming power of the effluent and the oxygen consumed as shown by the five-minute boiling test. Comparing Tables IX and X there will be noted the wide range in the quantity of chlorin absorbed by the effluent. The increase after a two and a

four hour contact, respectively, is also worthy of note. Comparing Tables X and XI there is obtained a rough indication of the effect of the concentration of chlorin upon the absorptive power of the effluent. Speaking generally, it may be said that there is an increased absorption as the organic content of the treated liquid increases, and also as the strength of applied chlorin increases.[a]

It appears that under conditions obtaining in these experiments chlorin up to 7.5 parts to the million would be absorbed from the sewage effluent in about 0.75 hour and that chlorin in concentrations of 10 parts and over would be detected in the treated effluent at the end of four hours. Additional experiments showed entirely different results, however; in one instance a chlorin concentration of 75 parts to the million could not be detected at the end of one hour. Data illustrating these points are given in Tables XIV and XV.

In continuing at Marion, Ohio, the study of the absorption of chlorin by organic matter and the possible relation between such absorption and the oxygen absorption shown by the standard oxygen-consumed process, there were carried out forty-eight separate experiments. These experiments dealt with the question of chlorin absorption and used, respectively, sand filter effluent, contact filter effluent, septic sewage, and crude sewage, each being prepared at different dilutions by the addition of tap water.

TABLE IX.—*Relative absorption of chlorin and oxygen by the Lancaster sand filter effluent with various quantities of tap water. Chlorin concentration of 500 parts to the million.*

Per cent of effluent.	Five minutes' contact.			Five minutes' contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
100	16	114	7.1	9.3	43	4.5
75	12	47	3.9	7.0	50	7.2
50	8	47	5.9	4.7	29	6.2
25	4	47	11.9	3.5	68	19.4
0	0	118	118.0	0.0	3	3.0

TABLE X.—*Relative absorption of chlorin and oxygen by the Lancaster sand filter effluent with various quantities of tap water. Chlorin concentration of 500 parts to the million.*

Per cent of effluent.	Five minutes' contact.			Four hours' contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
100	7.3	122	17.0	7.3	93	12.8
75	5.7	....	....	5.7	77	13.6
50	3.7	13	3.5	3.7	9	2.4
25	1.9	52	27.5	1.9	55	29.0
0	0.0	14	14.0	0.0	26	14.0

[a] This latter fact is noted by Rideal.

TABLE XI.—*Relative absorption of chlorin and oxygen by the Lancaster sand filter effluent with various quantities of tap water. Chlorin concentration of 100 parts to the million.*

Per cent of effluent.	Five minutes' contact.			Five minutes' contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Oxygen consumed (parts per million).	Ratio of chlorin to oxygen.
100	5.6	53.0	9.5	5.5	75.0	13.3
75	4.1	38.0	9.3	4.0	52.0	13.0
50	2.7	14.0	5.1	2.6	43.0	16.3
25	1.4	9.2	6.6	1.3	21.0	16.0
0	0.0	8.8	3.8	0.0	3.5	3.5

TABLE XII.—*Chlorin absorbed by crude sewage diluted with different quantities of tap water. Chlorin concentration of 500 parts to the million.*

Per cent of sewage.	Five minutes' contact.			Four hours' contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
100	166	266	1.60	166	390	2.34
75	123	202	1.64	123	354	2.69
50	83	174	2.09	83	238	2.87
25	42	68	1.62	42	102	2.42
0	0	118	118.00	0	118	118.00

TABLE XIII.—*Chlorin absorbed by crude sewage diluted with different quantities of tap water. Chlorin concentration of 500 parts to the million.*

Per cent of sewage.	Five minutes' contact.			Four hours' contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
100	46.0	245	5.3	46.0	327	7.1
75	24.0	32	1.3	24.0	132	5.5
50	13.0	122	9.4	13.0	167	12.8
25	6.5	72	9.0	6.5	114	17.5
0	0.0	14	14.0	0.0	26	26.0

TABLE XIV.—*Chlorin absorption when constant volumes of effluent are treated with different quantities of chlorin for different periods of contact. Volume of effluent treated, 500 cubic centimeters.*

Residual chlorin present indicated by +; absent, by 0.

Applied chlorin (parts per million).	Elapsed time (hours).								
	0.25.	0.50.	0.75.	1.00.	1.50.	2.00.	2.50.	3.00.	4.00.
2.0	0	0	0	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0	0
5.0	+	0	0	0	0	0	0	0	0
7.5	+	+	0	0	0	0	0	0	0
10.0	+	+	+	+	+	+	+	+	+
20.0	+	+	+	+	+	+	+	+	+
50.0	+	+	+	+	+	+	+	+	+
75.0	+	+	+	+	+	0	+	0	0

TABLE XV.—*Chlorin absorption when constant volumes of effluent are treated with different quantities of chlorin for different periods of contact. Volume of effluent treated, 500 cubic centimeters.*

Residual chlorin present indicated by +; absent, by 0.

Applied chlorin (parts per million).	Elapsed time (hours).								
	0.25.	0.50.	0.75.	1.00.	1.50.	2.00.	2.50.	3.00.	4.00.
2.0	0	0	0	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0	0
5.0	+	+	0	0	0	0	0	0	0
7.5	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	+
20.0	+	+	+	+	+	+	+	+	+
50.0	+	+	+	+	+	+	+	+	+
75.0	+	+	+	0	0	0	0	0	0

Generally speaking, the results of the somewhat exhaustive study of these chlorin-absorption phenomena were very much more consistent than the few data obtained at Lancaster. The work was carried out in a very systematic manner, better facilities were at hand for rapid operation, and consequently the results are to be considered much more reliable.

In tabulating the data they are presented in two different ways, the first intended to show the effect of the concentration of the applied chlorin upon the amount of absorption and the chlorin-oxygen consumed ratio and also the effect of the period of contact upon these same data. To this end, therefore, the four kinds of sewagic liquid studied are listed in Tables XVI to XXXV, inclusive, showing the average results for the different dilutions with tap water, the effect of the time factor and the strength of the applied chlorin upon the chlorin absorption and of the chlorin consumed to oxygen consumed ratio.

In Tables XXXVI to XLII, inclusive, are given the average results of the forty-eight experiments arranged with a view to indicate the effect of organic matter at different concentrations of applied chlorin, the tables being arranged as before with respect to the degree of dilution of the sewage under study.

From the summarized results of the chlorin-absorption studies tabulated the following conclusions may be drawn:

(1) The ratio of chlorin consumed to oxygen consumed in a five-minute period of contact bears no constant relation to the oxygen consumed by the five-minute boiling method.

(2) The concentration of applied chlorin affects the quantity of chlorin absorbed, the absorption at a concentration of 100 parts to the million being fully double that at 50 parts to the million.

(3) Increasing concentrations of chlorin up to 250 parts to the million increase the quantity of absorbed chlorin very materially, but

above this there appears to be very little increased absorption even with a chlorin concentration of 500 parts to the million.

(4) Increasing the period of contact to two hours effects but little increase in the ratio of chlorin consumed to oxygen consumed, except for the higher chlorin concentrations of from 250 to 500 parts to the million.

(5) The actual amount of chlorin absorbed in five minutes by the several liquids tested, under concentrations of chlorin of 50, 100, 250, and 500 parts to the million, ranged as follows:

Crude sewage	24 to 148
Septic sewage	41 to 160
Contact filter effluent	42 to 80
Sand filter effluent	33 to 68

(6) The absorption of chlorin apparently is largely dependent upon the organic content of the liquid treated, increasing materially as the oxygen consumed of the effluent increases, but not in a definite ratio.

(7) For the same concentration of applied chlorin the ratio between the chlorin consumed and the oxygen consumed appears to increase as the organic matters decrease.

(8) The readily oxidizable matter in the septic sewage studied apparently causes a rapid absorption of chlorin, increasing the chlorin-oxygen ratio, especially in the case of the lower concentrations of applied chlorin.

TABLE XVI.—*Relative absorption of chlorin and oxygen by crude sewage.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	94	34	0.36	36	0.38
100	94	60	0.64	63	0.67
250	94	144	1.50	178	1.90
500	94	148	1.60	209	2.20

TABLE XVII.—*Relative absorption of chlorin and oxygen by septic effluent.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	49	41	0.0	42	0.9
100	49	66	1.3	73	1.5
250	49	163	3.3	179	3.7
500	49	160	2.6	204	3.3

TABLE XVIII.—*Relative absorption of chlorin and oxygen by contact effluent.*

Concentration of chlorin (parts per million).	Five minutes' contact. Oxygen consumed (parts per million).	Five minutes' contact. Chlorin consumed (parts per million).	Five minutes' contact. Ratio of chlorin to oxygen.	Two hours' contact. Chlorin consumed (parts per million).	Two hours' contact. Ratio of chlorin to oxygen.
49	24	42	1.7	42	1.7
98	24	81	3.3	85	3.5
244	24	84	3.5	98	4.1
488	24	80	3.3	95	4.0

TABLE XIX.—*Relative absorption of chlorin and oxygen by sand-filter effluent.*

Concentration of chlorin (parts per million).	Five minutes' contact. Oxygen consumed (parts per million).	Five minutes' contact. Chlorin consumed (parts per million).	Five minutes' contact. Ratio of chlorin to oxygen.	Two hours' contact. Chlorin consumed (parts per million).	Two hours' contact. Ratio of chlorin to oxygen.
50	19	33	1.6	40	2.1
100	19	54	2.8	60	3.2
250	19	67	3.5	71	3.7
500	19	68	3.6	80	4.2

TABLE XX.—*Relative absorption of chlorin and oxygen by 75 parts of crude sewage diluted with 25 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact. Oxygen consumed (parts per million).	Five minutes' contact. Chlorin consumed (parts per million).	Five minutes' contact. Ratio of chlorin to oxygen.	Two hours' contact. Chlorin consumed (parts per million).	Two hours' contact. Ratio of chlorin to oxygen.
50	70	33	0.47	35	0.5
100	70	72	1.0	71	1.0
250	70	119	1.7	150	2.1
500	70	107	1.5	166	2.4

TABLE XXI.—*Relative absorption of chlorin and oxygen by 75 parts of septic effluent diluted with 25 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact. Oxygen consumed (parts per million).	Five minutes' contact. Chlorin consumed (parts per million).	Five minutes' contact. Ratio of chlorin to oxygen.	Two hours' contact. Chlorin consumed (parts per million).	Two hours' contact. Ratio of chlorin to oxygen.
50	37	36	1.0	40	1.1
100	37	85	2.3	86	2.3
250	37	125	3.4	141	3.8
500	37	123	3.3	173	4.7

TABLE XXII.—*Relative absorption of chlorin and oxygen by 75 parts of contact effluent diluted with 25 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
49	21	39	1.9	40	1.9
98	21	63	3.0	71	3.4
244	21	65	3.1	78	3.7
488	21	60	2.9	74	3.5

TABLE XXIII.—*Relative absorption of chlorin and oxygen by 75 parts of sand-filter effluent diluted with 25 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
49	14	28	2.0	33	2.3
97	14	51	3.6	56	4.0
244	14	51	3.6	54	3.9
486	14	53	3.8	63	4.5

TABLE XXIV.—*Relative absorption of chlorin and oxygen by 50 parts of crude sewage diluted with 50 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	47	29	0.6	30	0.64
100	47	71	1.5	78	1.7
250	47	80	1.7	118	2.5
500	47	83	1.9	112	2.4

TABLE XXV.—*Relative absorption of chlorin and oxygen by 50 parts of septic effluent diluted with 50 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	25	35	1.4	39	1.6
100	25	82	3.3	91	3.6
250	25	82	3.3	128	5.1
500	25	81	3.2	117	4.7

TABLE XXVI.—*Relative absorption of chlorin and oxygen by 50 parts of contact effluent diluted with 50 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
49	14	35	2.5	36	2.6
98	14	46	3.3	53	3.8
244	14	50	3.6	59	4.2
488	14	37	2.6	53	3.8

TABLE XXVII.—*Relative absorption of chlorin and oxygen by 75 parts of sand filter effluent diluted with 25 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
49	14	28	2.0	33	2.3
97	14	51	3.6	56	4.0
244	14	51	3.6	54	3.9
486	14	53	3.8	63	4.5

TABLE XXVIII.—*Relative absorption of chlorin and oxygen by 50 parts of crude sewage diluted with 50 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	23	36	1.6	40	1.7
100	23	43	1.9	55	2.4
250	23	43	1.9	70	3.0
500	23	28	1.2	59	2.6

TABLE XXIX.—*Relative absorption of chlorin and oxygen by 50 parts of septic effluent diluted with 50 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	25	35	1.4	39	1.6
100	25	82	3.3	91	3.6
250	25	82	3.3	128	5.1
500	25	81	3.2	117	4.7

TABLE XXX.—*Relative absorption of chlorin and oxygen by 50 parts of contact effluent diluted with 50 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
49	14	35	2.5	36	2.6
98	14	46	3.3	53	3.8
244	14	50	3.6	59	4.2
488	14	37	2.6	53	3.8

TABLE XXXI.—*Relative absorption of chlorin and oxygen by 50 parts of sand filter effluent diluted with 50 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
49	9	29	3.2	34	3.8
97	9	36	4.0	44	4.9
244	9	36	4.0	44	4.9
486	9	43	4.8	49	5.3

TABLE XXXII.—*Relative absorption of chlorin and oxygen by 25 parts of crude sewage diluted with 75 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	23	36	1.6	40	1.7
100	23	43	1.9	55	2.4
250	23	43	1.9	70	3.0
500	23	28	1.2	59	2.6

TABLE XXXIII.—*Relative absorption of chlorin and oxygen by 25 parts of septic effluent diluted with 75 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	12	41	3.4	48	4.0
100	12	56	4.7	57	4.8
250	12	47	3.9	62	5.2
500	12	48	4.0	72	6.0

TABLE XXXIV.—*Relative absorption of chlorin and oxygen by 25 parts of contact effluent diluted with 75 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
49	7	25	3.6	28	4.0
98	7	26	3.7	30	4.3
244	7	27	3.9	36	5.1
488	7	18	2.6	31	4.4

TABLE XXXV.—*Relative absorption of chlorin and oxygen by 25 parts of sand filter effluent diluted with 75 parts of tap water.*

Concentration of chlorin (parts per million).	Five minutes' contact.			Two hours' contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
49	5	21	4.2	26	5.2
97	5	24	4.8	27	5.4
244	5	27	5.4	24	4.8
486	5	24	4.8	41	8.2

TABLE XXXVI.—*Relative absorption of chlorin and oxygen, showing especially the effect of organic matter; 100 parts of sewage or effluent; contact period, five minutes.*

Concentration of chlorin (parts per million).	Oxygen consumed (parts per million).				Chlorin consumed (parts per million).				Ratio of chlorin to oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	94	49	24	14	34	41	42	......	0.4	0.9	1.7	......
100	94	49	24	14	60	66	80	......	0.6	1.3	3.3	......
250	94	49	24	14	144	160	84	......	1.5	3.3	3.5	......
500	94	49	24	14	148	160	80	......	1.6	3.6	3.3	......

TABLE XXXVII.—*Relative absorption of chlorin and oxygen, showing especially the effect of organic matter; 75 parts of sewage or effluent diluted with 25 parts of tap water; contact period, five minutes.*

Concentration of chlorin (parts per million).	Oxygen consumed (parts per million).				Chlorin consumed (parts per million).				Ratio of chlorin to oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	70	37	21	......	33	36	39	28	0.47	1.0	1.9	2.0
100	70	37	21	......	72	85	63	51	1.0	2.3	3.0	3.6
250	70	37	21	......	119	125	65	51	1.7	3.4	3.1	3.6
500	70	37	21	......	107	123	60	53	1.5	3.3	2.9	3.8

TABLE XXXVIII.—*Relative absorption of chlorin and oxygen, showing especially the effect of organic matter; 50 parts of sewage or effluent diluted with 50 parts of tap water; contact period, five minutes.*

Concentration of chlorin (parts per million).	Oxygen consumed (parts per million).				Chlorin consumed (parts per million).				Ratio of chlorin to oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	47	25	14	9	29	35	35	29	0.6	1.4	2.5	3.2
100	47	25	14	9	71	82	46	36	1.5	3.3	3.3	4.0
250	47	25	14	9	80	82	50	36	1.7	3.3	3.6	4.0
500	47	25	14	9	83	81	37	43	1.8	3.2	2.6	4.8

TABLE XXXIX.—*Relative absorption of chlorin and oxygen, showing especially the effect of organic matter; 25 parts of sewage or effluent diluted with 75 parts of tap water; contact period, five minutes.*

Concentration of chlorin (parts per million).	Oxygen consumed (parts per million).				Chlorin consumed (parts per million).				Ratio of chlorin to oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	23	12	7	5	36	41	25	21	1.6	3.4	3.6	4.2
100	23	12	7	5	43	56	26	24	1.9	4.7	3.7	4.8
250	23	12	7	5	43	47	27	27	1.9	3.9	3.9	5.4
500	23	12	7	5	28	48	18	24	1.2	4.0	2.6	4.8

TABLE XL.—*Relative absorption of chlorin and oxygen, showing especially the effect of organic matter; 100 parts of sewage or effluent; contact period, two hours.*

Concentration of chlorin (parts per million).	Oxygen consumd (parts per million).				Chlorin consumed (parts per million).				Ratio of chlorin to oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	94	49	24	19	36	42	42	40	0.38	0.9	1.7	2.1
100	94	49	24	19	63	73	85	60	0.67	1.5	3.5	3.2
250	94	49	24	19	178	179	98	71	1.9	3.7	4.1	3.7
500	94	49	24	19	209	204	95	80	2.2	3.3	4.0	4.2

TABLE XLI.—*Relative absorption of chlorin and oxygen, showing especially the effect of organic matter; 75 parts of sewage or effluent diluted with 25 parts of tap water; contact period, two hours.*

Concentration of chlorin (parts per million).	Oxygen consumed (parts per million).				Chlorin consumed (parts per million).				Ratio of chlorin to oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	70	37	21	14	35	40	40	33	0.5	1.1	1.9	2.3
100	70	37	21	14	71	86	71	56	1.0	2.3	3.4	4.0
250	70	37	21	14	150	141	78	54	2.1	3.8	3.7	3.9
500	70	37	21	14	166	173	74	63	2.4	4.7	3.5	4.5

TABLE XLII.—*Relative absorption of chlorin and oxygen, showing especially the effect of organic matter; 50 parts of sewage or effluent diluted with 50 parts of tap water; contact period, two hours.*

Concentration of chlorin (parts per million).	Oxygen consumed (parts per million).				Chlorin consumed (parts per million).				Ratio of chlorin to oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	47	25	14	9	30	39	36	34	0.64	1.6	2.6	3.8
100	47	25	14	9	78	91	53	44	1.7	3.6	3.8	4.9
250	47	25	14	9	118	128	59	44	2.5	5.1	4.2	4.9
500	47	25	14	9	112	117	53	49	2.4	4.7	3.8	5.3

SUMMARY AND CONCLUSIONS.

(1) It is desirable in many instances to remove from the sewage effluent bacteria which might be considered members of the pathogenic group. This is especially necessary when sewage is discharged in the vicinity of shellfish beds or when towns and cities are so intimately related that the standard methods of water purification can not sufficiently protect one community from the sewage of another.

(2) Both calcium hypochlorite and copper sulphate have high germicidal values when acting upon partially purified sewage. Calcium hypochlorite is much more rapid in its action, is more nearly able to bring about complete disinfection at a lower cost, and is less influenced by temperature and by the presence of carbonates. It is liable to deterioration upon standing and is more disagreeable and less convenient to handle than copper sulphate.

(3) The quantity of chlorin immediately absorbed can not be estimated from the determination of the oxygen-consumed factor of the sewage effluent.

(4) The cost per annum for each thousand gallons of sewage treated under the varying conditions experimented with is estimated as follows:

St. Mary's of the Springs, Ohio (average daily flow 12,000 gallons), crude sewage, copper sulphate, $18.55.

Westerville, Ohio (average daily flow 41,000 gallons), effluent from contact filter, copper sulphate, $11.77.

Boys' Industrial School, Lancaster, Ohio (average daily flow 160,000 gallons), sand filter effluent, copper sulphate, $6.93; chlorin, $5.78.

Marion, Ohio (average daily flow 600,000 gallons), sand filter effluent, copper sulphate, $4.86; chlorin, $2.43; contact filter effluent, chlorin, $2.73; septic tank effluent, chlorin, $8.83. In case the

effluent from the septic tank contains much suspended matter a heavier application of chlorin is necessary.

These figures probably approximate the cost for treatment in any city whose sewage is not markedly influenced by industrial wastes. In the small plants here discussed depreciation has not been included in the cost data; it is, of course, a factor which must not be overlooked for operating costs on a larger scale.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 116.

B. T. GALLOWAY, *Chief of Bureau*.

THE TUNA AS FOOD FOR MAN.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 23, 1907.

Sir: I have the honor to transmit herewith a manuscript entitled "The Tuna as Food for Man" and to recommend that it be published as Bulletin No. 116 of the series of this Bureau. This bulletin was prepared by Dr. David Griffiths, Assistant Agrostologist in Farm Management Investigations, Bureau of Plant Industry, and Prof. R. F. Hare, Chemist of the New Mexico College of Agriculture and Mechanic Arts.

This bulletin represents three lines of investigation—a study of the uses of the tuna (pronounced *too-nah*), a study of the chemical composition of the tuna, and a study of the tuna products as manufactured by the primitive peoples of the Republic of Mexico. The authors have joined these three lines of work in one report.

There is presented in the paper actual economic practices which are of interest not only to portions of the United States but to some of its insular possessions as well, botanical data necessary to the recognition of different species and varieties, and a large amount of chemical information of unusual interest. The botanical notes have been abridged as much as is consistent with a clear presentation. In many cases they have been omitted almost entirely; in all such cases, however, they will be found more fully presented in Bulletin No. 60 of the Agricultural Experiment Station of New Mexico.

Interest in cacti in general, from both a food and a forage standpoint, has been greatly stimulated by popular writers during the past two or three years, and such investigations as are here recorded are therefore of special value at this time. In order to secure a basis for future investigations in the development of forms better adapted to our use, it has been necessary to treat the subject from the broad point of view of the entire continent rather than of the United States only. A few valuable tunas are now grown within our borders, while the Mexican species are very numerous. Many of the latter have very desirable characteristics which if combined

with species now grown here would make a very superior fruit. The data presented in this bulletin, while intended mainly as an account of the tuna as it exists to-day in the United States and Mexico, furnish a foundation for future investigations in the development of more desirable forms, a work which is now in progress.

Tuna is the Spanish name for the fruit of the prickly pear plant—that section of the botanical genus Opuntia which bears flat-jointed stems. A discussion of the fruit of one Opuntia with cylindrical joints is also included in the bulletin for reasons stated in the text. Many other cactus fruits should be investigated. Some work has already been done upon them and will be continued as time permits. The term pitalla (pronounced *pee-tah-ya*) is used by the Mexicans for a very large and heterogeneous group of cactus fruits belonging to such botanical genera as Cereus, Echinocereus, Echinocactus, Pilocereus, etc.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE TUNA AS FOOD FOR MAN.

INTRODUCTION.

The prickly pear of the American and the Australian, the Indian fig of the Englishman, the Barbary fig of the Frenchman, the tuna of the Spanish-American, and the higos chumbos of the Spaniard is a fruit concerning which there are more varied beliefs, contradictory opinions, and grades of appreciation than any other known to us. The plant and its fruit are subjected to both praise and abuse.

While the Mexican prays that there may be no rain when the plants are in bloom, in order that the fruit may set well and produce a good crop of tunas, the legislative assemblies in some of the Australian colonies pass laws looking toward their eradication. While the Australian governments spend much money to eradicate the "weed," some ranchmen find that it can be fed to stock with profit. While the southern Texan was imploring the Government in the early nineties to conduct investigations looking to the eradication of prickly pear, shrewd cattlemen and ingenious machinists were devising means whereby it could be divested of its objectionable characteristics at small expense and turned to profitable use. While the minister of agriculture of India pronounced against its use in unqualified terms, it was found that it could be profitably used in both beef production and dairying in at least one section of the United States. While the South African is said to revile its presence, the poorest inhabitants of the Island of Sicily are reported to subsist largely on its fruit for three or four months of each year. The average American traveling in Mexico can see no value whatever in the tremendous stretches of prickly pear upon the plateau, but the native peon grows these and similar cacti in his orchards and gives them fully as careful attention as any plants which he attempts to cultivate.

Enthusiastic magazine writers would revolutionize conditions in arid regions by the establishment of plantations of prickly pear without spines, thus converting the most arid deserts into populous, prosperous communities. Experience teaches, however, that the spineless varieties of cultivation are not hardy under natural desert conditions, that all of the valuable spineless species which produce either fruit or forage in economic quantities require considerable

precipitation at some time during the year, and that economic species are not known which thrive under a minimum temperature of less than 10° F. One exception to this may be noted in the case of *Opuntia arborescens* of Colorado; but the quantity of stock feed produced by this species is comparatively small and its distribution limited.

Conservative judgment based upon observation and experiment, on the other hand, would pronounce many species of prickly pear to be decidedly susceptible to cultivation and highly productive of both fruit and forage under proper conditions of temperature and moisture. It is also true that there are species which thrive under moderate extremes of heat; that, as a rule, they are adapted to conditions of periodical rainfall and thrive where the distribution of moisture is too irregular and uncertain for commonly cultivated crops; that the spines and spicules have been practically eliminated from the plant body in valuable species but not from the fruit; that all of the so-called spineless forms concerning which there is definite knowledge are less hardy, especially under conditions of drought, than spiny native forms; that it is quite probable that by persistent breeding and selection the spines and spicules may be more completely removed and the plants bred to withstand a greater degree of cold; that the plants can be fed with concentrated foods with profit; that the fruit is now, in its spiny condition, an important and highly prized constituent of the diet of the poorer classes, especially of Mexico and Sicily; that very desirable food products are prepared from the fruits, and that the group is of sufficient economic promise to merit thorough investigation.

THE COMMON NAMES OF TUNAS.

The common names which are used in this bulletin have been selected with the utmost care. They are based upon a careful investigation of all of the important prickly pear regions of the United States and Mexico. Unless otherwise indicated, it is believed that they are accurate. In each instance, unless the name is questioned in the text, it has been verified many times. The orthography of the common names has, in nearly every case, been verified by educated Mexican gentlemen and accords with the ideas of the writers concerning derivation. Señor Enrique L. Guerra has corrected the list of popular names and has made important suggestions and contributed much valuable information upon all phases of the subject.

The popular names are as a rule quite the same in any one locality, but there may be great variation between the names of species in different localities. Some well-marked species, however, have appar-

ently the same name wherever found. The use of the names cardon, tapon, camueso, and amarillo is, so far as the experience of the writers goes, universal; but these are very characteristic species which even the least observant can not well mistake. It is entirely different with the yellow or green fruited forms (including the tame or cultivated ones). These have a multitude of names. Some of them may and probably do represent good specific distinctions. On this point it is impossible to speak with certainty, for the writers' experience with the different forms has not been sufficiently extensive. Some of the plants are spiny, others almost perfectly spineless, and even in some cases apparently without spicules on either fruit or joint. In general aspect they are all very much alike, and the names applied to the different forms do not appear to be at all uniform. Some of the names used for the greenish-white-fruited forms, for example, are as follows: Nopal blanco, nopal teco, nopal paloalteno, nopal fafayuco, nopal Mexicano, nopal Americano, and nopal Castillo blanco, while nopal liso is commonly used, though the latter name is applied to any thornless form. They all appear to be closely related to one form of our southwestern "mission pear," although in this country this is nearly always a thorny form, while the greenish-yellow-fruited forms of Mexico may exhibit any degree of spininess.

It must be understood that any list of common names of Mexican tunas can be of only tentative value, for there may be even less uniformity in popular names in Mexico than in this country. In any one locality, however, the name used for a species or variety is reasonably constant. The commercial spirit has had no influence in changing names.

As with many other natural and agricultural subjects, it is the native peon who is the court of final resort to decide upon the names of plants. The rancher when asked regarding such matters will almost invariably put the question to one of his more intelligent servants. The names used in this bulletin have been obtained mainly from the peons and have subsequently been verified and corroborated by educated and intelligent ranchers.

THE CULTIVATION OF THE NOPAL.

There are in Mexico many varieties of prickly pear which are found only in cultivation. This is especially true of the spineless forms in general. Others are native and may or may not be cultivated. Of the first group the peon may speak collectively as mansas, or tame forms, but he has names for all of the varieties which are grown in his orchards as well as for the wild ones of the mountains. To say that any of the forms are cultivated as we think of cultivation in

this country, however, is a gross error. They are rarely cultivated at all. Cuttings are put into the ground and surrounded by a fence to protect them from animal depredations. Aside from this they get little or no attention.

A plantation is always started from cuttings; consequently it is an easy matter to maintain uniformity in the plants. Inasmuch as it is always an object to get tunas as soon as possible, the stock-feed feature of the crop being always a secondary consideration, cuttings of three joints are planted when possible. (See Pl. V, fig. 2.) A cutting consisting of two and a half joints is common. When planted in this way it is said that a crop of tunas is produced the third year, while it takes five years to get a crop from one-joint cuttings.

Plantations are not confined to the mansas. On the contrary, the wild forms will often be found in the orchards under protection and are even planted without protection in the hills. Such forms as the cardon are admirably adapted for this purpose, for no animal can molest them much. The thickets of this species east of San Luis Potosi have been greatly extended by planting cuttings in unoccupied areas. Several acres were planted there last year. How much of this has been done in the past it is difficult to say, for it is not always easy to tell the difference between areas which have been planted and those which are wild. Quite likely many of the thickets found in the hills have been, in a measure, established through the influence of man, some of them unwittingly, for the method of collecting the fruit scatters joints about, many of which strike root and grow. Some of the thickets in the vicinity of Alonzo, Mexico, are being slowly extended by this method of collecting the fruit.

THE TUNA MARKETS.

A very distinctive feature of the markets of the different cities of the highland region of Mexico is the space or booths assigned to the sale of tunas. The business is generally carried on by the poorer people in the most simple and primitive way. Not that the poor are the only ones who eat tunas, but they are eaten more extensively by the poorer class than by any other.

During the greater part of the season purchasers come to these booths—distinguished by the size of the individual awnings or by the length and number of the benches and stools—where they may purchase one or more varieties of fresh tunas at a very low price. The purchaser is supplied with a stool, upon which he can sit, and a knife with which to peel the tunas. During the height of the season when the fruit is cheapest, women appear on the markets each morning with huge baskets of peeled fruits, which they lay out in earthen

saucers, each containing a quantity which is disposed of for 1 cent. Each purchaser is furnished with a tip of a maguey leaf or a thorn of the mesquite with which to eat the pulp, and in a few instances modern wooden toothpicks are served with them.

By far the greater quantity of fruit is sold unpeeled. This is especially true during the season when fruits are not abundant, for less waste results then than when the tunas are peeled. Sometimes the purchaser peels the fruit himself and at other times he eats it as the vendor or his attendant peels it for him.

The process of peeling on the market is practically the same as described later, the knife being run across the top and down one side to the base, when the pulp may be picked out easily. When fully ripe much of the rind of some species is consumed with the pulp. The tuna is taken between the thumb and forefinger of the left hand and the rind cut off with a sort of whittling motion of the knife, each stroke taking off the epidermis and a portion of the rind, but not more than one-half of the rind is ever eaten. In peeling the larger mansas (cultivated forms), both ends are usually cut off and an incision made through the rind lengthwise between these two cut surfaces, when the remainder of the outside is removed by pushing it back with thumb and forefinger of each hand.

To remove the spicules so that the fruit can be more easily handled the vendors employ several simple devices. Sometimes the tunas are rolled around upon the sand with the aid of a bundle of small twigs or a bunch of weeds. At other times they are actually brushed with a wisp of grass or a brush made of maguey fibers. Often they are stirred in a pail of water. Any of these processes will remove the spicules fairly well if the fruit is thoroughly ripe. It should be remembered that there are no prickly pears without spicules. Even the so-called thornless ones which have been developed in the Mediterranean region, and eight or ten of which have been apparently produced in Mexico, have some spicules upon the fruit, although the spines have been quite effectually bred off the body of the plant. Also, in nearly all cases there are produced upon the fruits hairlike, fugacious spines, most of which drop off or are easily removed when the fruit is ripe. The spicules are the most serious obstacle to the use of this fruit.

As previously stated, it is the pulp which is usually eaten; less often some rind is also consumed with it. It is well known that the pulp itself is very seedy, and on this account the fruit is very objectionable to the average American; the Mexican, however, swallows seeds and all with apparent indifference. The species of which both the pulp and rind are eaten are mainly cardonas late in the season, and durasnillas. In the latter fruit the pulp is not easily separated from the rind, but in the former the rind is removed without difficulty.

The price of tunas upon the market varies greatly with the season. During the past year the cheapest were found at San Luis Potosi, where 15 to 20 cardonas were sold for a cent [a] and the large mansas as low as six for a cent. In Guadalajara, where tunas are rare, three to five cardonas were commonly sold for a cent and one amarilla, naranchada, or other mansa for the same price. During the month of August cardonas were selling wholesale at San Luis Potosi for about 45 to 50 cents a crate of a thousand tunas; at the same time they were sold upon the market at the rate of 14 for a cent. It is said that one man can pick about three crates a day.

An attempt was made to determine how much of this fruit is eaten by the average peon in a day, but with no satisfactory results. The writers have repeatedly seen men eat from 25 to 50 tunas without stopping, and peons affirm that they eat an average of about 100 a day. It is believed, however, that where the diet is made up largely of tunas, and they are conveniently at hand, upward of 200 a day are consumed by one individual. Intelligent and conservative ranchmen estimate that a man will easily consume many more than 200 cardona pears per day when in the hills where practically no other food is available. This fruit represents very often in the largest measure both food and drink, but it seems like a very heavy ration when one considers that the seeds as well as the pulp are swallowed. It has been the experience of the writers that one not accustomed to the fruit can eat 60 to 80 tuna cardonas a day if the seed is not swallowed, and they have eaten as many as this occasionally in about two hours' time.

It must be remembered that the pulp of 40 to 50 tunas (cardonas) forms quite a bulky meal; the seeds are, of course, not digested. It is claimed that only a few of the species can be eaten in large quantities without danger. There is said to be no danger from eating any number of cardonas unless it be immediately after a heavy meal consisting largely of meat. On the contrary, it is claimed that the mansas must be partaken of sparingly on account of their interference with digestion when eaten too freely. Peons are very careful in eating taponas because they believe that these fruits produce intense constipation. They claim that death has resulted in some cases from eating too much of this fruit.

The excreta, both solid and liquid, are decidedly colored when the red tunas, especially taponas, are eaten. So far as the writers have been able to learn, however, the tuna cardona is the universal favorite and apparently its use as food results in no injury whatever, even

[a] Unless distinctly specified to the contrary, the prices quoted are in Mexican currency. Equivalents for the United States can be determined approximately by dividing by two. A Mexican dollar equals 50 cents of the currency of this country, while a cent in Mexican money is worth only half a cent in the money of the United States.

when partaken of very freely. The explanation offered by the natives as to the injurious effects of the mansas is that they are too rich.

Where there are so many tunas consumed there is, of course, a large quantity of rind available for stock food, while in the manufacture of queso and other products the quantity of seed taken out is quite large. Upon one ranch visited the by-products were fed to hogs. Upon the markets at San Luis Potosi during the month of August the rinds were selling at the rate of 10 to 12 cents a basket of about 50 pounds and were consumed largely by dairy cattle. They were also fed to burros and swine.

GENERAL DESCRIPTION OF THE FRUITS.

The fruits of the prickly pear vary in size, shape, and color, depending upon the species and the conditions under which they are grown. They are from 1 to 3 inches in diameter and are usually pear-shaped or fig-shaped, but in some species they are nearly spherical. They weigh from an ounce to a half-pound or more and vary when ripe from a yellowish green to a dark purple.

All varieties have minute spicules arranged in bunches over their surface, there being about one bunch to every square inch of surface in the best varieties, but in most species they are more numerous than this. The fruits of nearly all of the species have large spines also, which are similar to those on the plant body, but are much more delicate and usually drop off before the fruits are thoroughly ripe. A cross section of the fruit shows it to be covered with a thin skin, or epidermis, underneath which there is a rind varying in thickness from one-eighth to one-half of an inch. This includes the pulp, or edible portion, in which there are found embedded from 100 to 200 or more seeds. In some fruits as many as 400 have been counted.

THE EPIDERMIS.

The epidermis is the thin outer skin, and, whether the fruits are eaten raw or in conserved products, it is necessary that this be removed because of the tiny spines occurring in bunches over its tough, leathery surface. When the fruits are peeled, a part of the rind is removed along with the epidermis.

THE RIND.

The fruit itself is found enveloped in what is morphologically a portion of the stem, but which we have called rind. It partakes of the nature of both fruit and stem, usually assuming the color of the fruit and somewhat approaching it in composition. In some varieties it contains sufficient sugar to make it edible, but it usually retains so much plant mucilage, always present in the stems, that it

is not as palatable as it would otherwise be. Except in the formation of some sugar as the rind ripens and the change in coloring matter, the rind retains the general cell structure and appearance of the stems.

The rind is usually easily separated from the pulp. It constitutes from 25 to 75 per cent of the fruit, and when this is not eaten there is, of course, a very large percentage of waste. Consequently, the fruit which has the thinnest rind is the most desirable.

In a number of species where the waste was large and the rind was at all palatable, a separate analysis was made of the rind to determine its nutritive value compared with the pulp. The results are given in Table I. By comparing the results given in this table with the analyses of the pulp in Table II it will be seen that the percentage of both the total and soluble solids of the pulp is greater than that of the rind. In fact, about 50 per cent of the solids of the rind are in an insoluble form, whereas in the pulp the solids are almost completely soluble. In the rind the acid is always comparatively high, as is also the alcohol precipitate, both of which make the fruits unpalatable. The specific gravity of the juice of the rind is always less than that of the pulp, and the sugar content is also much smaller. The results of our analyses show that the rind at times contains some sucrose, which seems more often to be lacking in the pulp.

TABLE I.—*Analyses of the rind of tunas.*

Collector's number.	Scientific name.	Common name.	Number of fruits per pound.	Weight.	Waste (peeling).	Composition.																	
						Total solids.	Soluble solids.	Specific gravity of juice.	Total solids in juice.	Total proteids.	Albuminoids (N×6.25).	Amids (N×4.25).	Water-soluble proteids (N×4.25).	Acids expressed as H_2SO_4.	Polarizations. Direct.	Polarizations. Invert.	Temperature.	Sucrose by polarization.	Sucrose by reduction.	Total sugars as dextrose (Allihn).	Ash in soluble solids.	Alkalinity of ash as K_2CO_3.	Alcohol precipitate (mucilage, salts of organic acids, etc.).
				Grams.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*			° *C.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
8065a	Opuntia robusta..	Tuna tapona ...	2.20	210.60	......	......	......	1.041	9.85	......	......	......	......	0.130	+1.3	+1.30	34	0.00	......	......	......	......	......
8057	Opuntia sp.........	Tuna amarilla..	4.80	94.00	30.85	......	......	1.038	9.15	......	......	......	......	0.231	+0.20	+0.20	28	0.00	0.57	4.09	......	......	......
8051	Opuntia streptacantha.	Tuna cardona ..	10.34	43.83	38.01	......	......	1.030	7.27	......	......	......	......	......	......	......	......	......	0.62	4.49	......	......	......
8099	.....do.............	.....do..........	9.06	50.00	29.42	14.96	12.81	1.040	9.62	0.193	0.104	0.088	0.149	0.211	......	......	......	......	......	......	1.38	0.249	......
[1] 8099	.....do.............	.....do..........		......	......	10.40	10.03	1.040	9.62	0.166	0.122	0.044	0.141	0.211	+2.3	+0.90	30	1.05	1.58	6.63	1.10	0.223	......
[2] 8099	.....do.............	.....do..........	9.24	49.00	38.29	......	......	......	......	......	......	......	......	......	+2.2	+1.20	30	0.75	......	7.74	......	......	......
[3] 8099	.....do.............	.....do..........	9.64	47.00	49.73	13.35	11.37	1.040	9.62	0.244	0.104	0.140	0.179	0.215	+2.8	+0.80	29	1.50	1.32	7.74	0.250	0.207	1.800
8100	Opuntia sp.........	Tuna chaveña..	6.80	66.50	58.48	......	......	1.032	7.74	......	......	......	......	0.955	+0.4	+0.40	28	0.00	0.79	4.97	......	......	......
8119	.....do.............	Tuna agua-mielilla.	14.70	30.84	46.72	......	......	1.030	7.27	......	......	......	......	0.497	+1.3	+0.80	29	0.38	0.00	2.76	......	......	......
8135	.....do.............	Tuna joconoxtle	11.00	41.17	55.76	6.71	4.37	1.025	6.09	2.830	0.104	0.179	0.223	0.443	+1.3	+0.40	27	0.69	0.00	3.31	1.19	0.808	0.233
8143	Opuntia leucotricha.	Tuna durasnilla blanca.	10.60	42.90	58.40	10.22	6.92	......	......	0.190	0.130	0.060	0.074	0.910	+0.4	−0.50	24	0.68	1.05	6.08	0.79	0.700	......
8150	.....do.............	Tuna durasnilla colorada.	11.10	40.60	58.86	8.95	7.17	1.036	8.68	0.228	0.109	0.119	0.100	0.435	+1.6	+0.40	25	0.89	2.06	6.63	0.89	0.570	0.760
	Average......	....	9.04	65.13	46.14	10.77	8.78	1.035	8.49	0.217	0.112	0.105	0.144	0.424	+1.4	+0.59	28.4	0.59	1.89	5.44	0.93	0.460	1.630

[1] Juice only. [2] Ten days after gathering. [3] Twenty days after gathering.

THE PULP.

The pulp is the portion of the fruit that is eaten in all varieties. In some species it is insipid, but in many it has an excellent flavor. We believe that Americans will acquire a liking for this fruit more readily than they do for tropical and subtropical fruits in general. The amount of pulp in the different varieties varies from 30 to 65 per cent, and as a rule those with a large percentage of pulp have the best flavor.

The structure of the pulp is rather peculiar for a fruit. The walls of the cells are very thin, and there is consequently very little fibrous substance in its make-up, and, indeed, but little insoluble solids in the majority of the species. By pressing the pulp in muslin bags practically the entire quantity can be forced through the meshes of the cloth. This was found to be the most satisfactory method of separating the seed from the pulp, and was adopted in our analytical work. The small amount of fibrous tissue is shown by the quantity of insoluble solids, which averages less than 1 per cent for all the samples.

There is great variation in the composition of the pulp of different species and even of the same species at different seasons or degrees of ripeness. The amount and character of the edible matter vary a great deal in the different samples, as will be seen when the various constituents of the edible portion are discussed. Several varieties have been worked in duplicate, and by referring to the tables it will be seen that frequently the two analyses are very different. This may be accounted for in several ways. In the first place, the fruit may be eaten at varying degrees of ripeness. The pulp of the tuna tapona, for instance, is palatable at least two weeks before the outside of the fruit turns red and is commonly eaten from the time the pulp turns red until the outside is a deep purplish color. The time which it takes for these changes to occur in the fruit is not less than a month. Browne[a] has found that apples, and Bigelow[b] that peaches, vary a great deal in composition at their different periods of growth, and in all probability the same would be found true of fruits of the cacti. The season, climatic conditions, and soil fertility no doubt affect the composition of this fruit as they do all others.

THE SEED.

The seeds (see Pl. VI) are distributed throughout the mass of the pulp. They are somewhat disk shaped, and are from one-eighth to three-sixteenths of an inch in diameter. The seed coats are very hard and are never masticated or digested when the fruit is eaten. Each fruit contains a large number of seeds, varying somewhat with the different varieties. Some of the samples analyzed had no more

[a] Pa. Dept. Agr., Bul. 58.

[b] U. S. Dept. Agr., Bureau of Chemistry, Bul. 97.

Composition of edible portion.

Water-soluble proteids (N×4.25).	Acids expressed as H_2SO_4.	Polarizations.		Temperature.	Sucrose by polarization.	Sucrose by reduction.	Total sugars as dextrose (Allihn).	Ash in soluble solids.	Alkalinity of ash as K_2CO_3.	Alcohol precipitate.
		Direct.	Invert.							
Per ct.	*Per ct.*			°*C.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
0.156	0.700	+0.300	−0.400	30	0.53	0.00	7.18	0.17	0.027	....
....	1.180	....	....	......	....	....	0.85	....	....	....
0.284	0.880	−0.500	−0.700	26	0.15	0.41	5.24	0.42	0.276	0.394
....	....	±0.00	±0.00	24	0.00	0.00	1.41	....	....	....
....	2.150	....	....	......	....	....	0.00	....	....	....
0.220	1.228	−0.067	−0.367	27	0.23	0.14	2.94	0.30	0.152	0.394
0.252	....	+2.00	....	......	....	0.35	9.76	0.37	0.033	....
0.268	0.038	+1.10	+0.700	29	0.30	0.00	11.05	0.24	0.062	0.200
....	....	+2.40	+2.400	30	0.00	0.00	8.84	....	....	....
0.149	0.076	+2.30	+2.000	29	0.15	0.00	9.95	....	....	0.200
....	0.040	+1.50	+1.108	28	0.31	0.58	11.05	0.23	0.140	0.394
....	....	+1.20	+0.300	20	0.68	1.04	9.07	....	....	....
....	....	....	....	......	....	0.69	10.44	....	....	....
0.164	0.320	+1.00	+1.000	25	0.00	0.00	8.84	0.30	0.460	0.180
0.100	0.079	+0.30	+0.300	25	0.00	0.00	8.84	0.27	0.170	0.210
....	....	+0.80	−0.100	24	0.68	0.26	7.08	....	....	....
0.387	0.078	+1.80	+1.60	26	0.15	1.58	8.29	0.20	0.120	0.250
....	....	+1.00	+0.50	24	0.38	0.32	8.99	....	....	....
0.342	0.062	+0.90	+0.80	26	0.08	0 00	9.12	0.20	0.180	0.280
....	....	−0.20	−0.50	24	0.23	0.46	9.31	0.21	....	....
0.208	0.077	+0.20	−0.30	30	0.38	0.00	11.07	0.74	0.117	....
....	0.047	−0.70	−0.70	25	0.00	0.60	11.70	0.29	0.180	....
0.431	0.031	+2.10	+2.10	25	0.00	0.00	9.12	0.28	0.166	0.280
0.573	0.031	−0.60	−0.60	25	0.00	0.00	11.05	0.34	0.194	0.280
0.216	0.071	+1.30	+1.10	27	0.15	0.00	7.74	0.11	0.200	0.231
0.134	0.062	+2.30	+2.10	29	0.15	0.00	10.22	0.25	0.111	....
0.231	0.024	+1.30	+1.10	30	0.15	0.00	8.84	0.02	0.027	0.151
0.327	0.046	+2.10	+1.60	29	0.38	0.00	10.78	0.27	0.048	....
0.114	0.037	+0.40	+0.40	29	0.00	0.00	9.39	0.10	0.034	....
0.179	0.070	+1.70	+1.40	28	0.24	0.00	9.12	0.20	0.124	0.28
0.193	0.210	±0.00	±0.00	......	0.00	0.00	9.39	0.32	0.033	....
....	0.073	+0.90	+0.90	30	0.00	0.00	....	....	....	....
0.252	0.071	+0.30	+0.30	30	0.00	0.00	8.74	0.34	0.330	0.207
0.251	0.080	+1.05	+0.78	27	0.17	0.22	9.53	0.36	0.160	0.242
0.186	3.480	±0.00	±0.00	......	0.00	0.00	0.00	0.83	0.124	....
....	0.626	+1.30	−2.50	28	2.92	2.80	9.30	[1] 1.13	....	....

rtion.
cilage made it impossible properly to determine specific gravity.

than 75 seeds, while others contained as many as 400. The average weight for the wild forms from Texas was 7.54 per cent of the whole fruits, while in one sample of a cultivated Mexican variety there was only 1.52 per cent of seeds. The larger cultivated fruits always have proportionally fewer seeds, and it may be that in time cultivation and selection will still further reduce the number.

THE REFUSE.

The waste in eating the cactus fruit consists of the seeds and such part of the rind as is rejected—when the rind is eaten, the waste is the seed with only that part of the rind which is lost in peeling the fruit. Since such a large percentage is rind, the waste is very large when this is rejected. In one variety, tuna chaveña (No. 8136), it amounted to 78.17 per cent. The fruit having the smallest amount of waste of all the prickly pears was No. 8142, tuna naranjada—only 37.43 per cent. The average for the Mexican samples was 56.18 per cent. The samples received from San Antonio, Tex., *Opuntia lindheimeri*, averaged 71.56 per cent of refuse.

The watermelon has 59.4 per cent waste; the muskmelon, 50 per cent; bananas, 35 per cent; oranges, 27 per cent; apples, 25 per cent, and pears, 10 per cent.[a] Thus it will be seen that the tunas, when the rind is rejected, have about the same proportion of refuse as the melon, and when the rind is eaten about the same as other fruits.

HARVESTING THE TUNA.

The method of harvesting the tuna is influenced both by the variety gathered and the purposes for which the crop is to be used.

HARVESTING FOR IMMEDIATE CONSUMPTION.

It is common for the peon to get a large portion of his living during the tuna season from the plants as they stand in the field. (Pl. II, fig. 1.) A large part of the crop is therefore consumed directly from the plants. The object of the picker in such cases is to get the edible pulp separated from the remainder of the fruit with as little difficulty as possible. A sharp knife is used to make an incision across the top of the fruit and curving down on one side to, or nearly to, the attachment. Then the thumb and forefinger of the left hand are forced down between the rind and the pulp, loosening the latter and forcing it upward, when it is caught between the thumb and the index and middle fingers and removed without coming in contact with the small spines at all. The incision is made only to such a depth as will expose the pulp, and none of the rind is removed from the trees. Of course

[a] U. S. Dept. Agr., Office of Experiment Stations, Bul. 28.

this method applies only to such fruits as are in reach of the picker and is practiced by those who eat as they gather in the field. The method of securing the tunas growing beyond reach of a man standing upon the ground is described later.

GATHERING CULTIVATED FORMS.

As stated elsewhere, the mansas or tame forms are not disfigured by cutting the joints as are the wild ones. The vast majority of the cultivated tunas is produced beyond the reach of a man on the ground, and these are collected with a long pole (usually bamboo). The end of this pole is divided into three or four equal segments, which are held apart by a wooden plug secured firmly in place by thongs of rawhide or maguey (Agave) fiber. This makes a conical receptacle in the end of the pole which is thrust around the tuna, the latter being removed by twisting the pole. In this process of gathering, the fruit is more or less injured either by the end of the stick itself or by the wrenching process used in loosening it from the tree. Sometimes the fibers entering the tuna from the joint are twisted off, leaving a lacerated hole in the end of the fruit. At other times the base of the tuna itself is twisted off. It is evident that fruit injured in this way will not keep long. A large part of the fruit of the cultivated forms upon the markets, however, is gathered in this way.

GATHERING WILD FORMS.

Whenever the preservation of the plants is not an important consideration, the Mexican gathers the tunas which are beyond his reach with a gancho (hook), made by fastening a strong knife blade at right angles to a long pole. (See Pl. II, fig. 2.) With this he cuts the joint nearly off, thrusts the point of the gancho into the severed portion, and lowers it to the ground. Commonly but very little attention is paid to the quantity cut from a plant, the place of the incision depending upon the number and distribution of the tunas. Often two or three joints are taken off together, but more commonly only that portion of the one containing tunas is removed.

After the joints have been lowered to the ground in this way the pulp is removed as previously described, the operator either standing in a bent-over position, with one foot upon the segment of the joint, or kneeling upon one knee. (Pl. II, fig. 2.)

GATHERING FOR THE MARKET.

When tunas are desired for the market, for shipment, or for storage in a fresh condition, more care is exercised in picking them. Instead of tearing or twisting them from the joints, they are carefully cut off

with a sharp knife. The fruit is taken between the thumb and the forefinger and middle finger of the left hand and pushed to one side slightly, when with the point of a knife its connection with the stem is severed. The difficulty of this operation may not be apparent to the reader unfamiliar with the small spines with which the fruits are protected. The handling must be very carefully done. The native becomes so adept that he grasps the fruit between the cushions of spines with little likelihood of being injured. Owing to the fact that there is no appreciable fruit stem, as there is in the apple, peach, and pear, it is difficult to remove the fruits from the trees without injuring them. Italian shipments upon the markets of this country usually have a small portion of the joint attached to the fruit. It is usually less difficult to collect tunas in this way; but the small piece of joint probably gives no advantage over a perfect fruit removed without it. The difficulty in picking without injury varies with different varieties and in the same variety under different conditions of development. A plump fruit is much more difficult to remove without injury than one which is shriveled, as will be readily apparent. Such forms as the amarilla, naranchada, camüesa, etc., which are shaped somewhat like the common pear, are more easily picked than the more nearly globular forms, such as cardona, chaveña, etc.

EFFECTS OF CUTTING OFF THE JOINTS IN HARVESTING.

Personal observations of the thickets and the opinions expressed by the more intelligent people lead us to believe that, on the whole, cutting off the joints results in injury to the succeeding crop of tunas. Fruits are produced upon the last year's growth, and if this be very severely pruned, as is often the case when a large crop is harvested with the gancho, the growth the following season consists very largely of vegetative joints and not fruits; but the second year after a severe pruning a large crop of fruit is likely to be produced. In fact, the pruning is not wholly a bad practice, for the joints strewn over the ground often give rise to new plants, thereby extending the thickets.

THE KEEPING QUALITIES OF TUNAS.

Contrary to popular opinion, some tunas can be preserved in the fresh condition, if properly handled, about as long as the common fruits of the temperate zone. It is not at all uncommon to find the Italian forms upon the markets of the chief cities of this country in the autumn and early winter. These withstand transportation, besides two or three months in storage on this side of the ocean. The writers have had samples of yellow tunas of Italian origin obtained

upon the markets in Washintgon city remain in good condition in their possession for two months while subjected to the irregular temperatures of an ordinary living room.

Like all other fruits, different forms have different keeping qualities, and freshness is of longer duration when the picking is done before maturity than when dead ripe. Cardonas will remain good for twelve to fifteen days upon the open markets of Mexico after being picked and carried on burros a distance of 10 to 20 miles. The mansa forms keep longer if cut instead of being twisted or pulled off. The best keepers are without doubt some of the forms of joconoxtle and chaveña. The latter is the one commonly kept over winter in the region of Aguascalientes. The packing of this species is a regular business, and it may be found upon the markets as late as the 1st of May. It is one of the latest tunas to mature in the fall and has a comparatively thick, firm rind, well adapted for storage. On the whole, it may be said that tunas are easily injured, and consequently much care is necessary in handling them when they are intended for packing. They must also be well aerated in storage, which is true of all fruits.

At the present time there is quite an extensive shipment of tunas by rail from place to place in Mexico. The writers happened to be in Torreon on a Sunday during September, 1906, when a carload was brought from near Aguascalientes. It contained cardonas mostly, but also some fafayucas, amarillas, naranchadas, and durasnillas. They were shipped loose in an ordinary box car, piled upon the bottom of the car to a depth of about 2 feet. They are commonly shipped packed in crates with straw, the crate being usually a little smaller than our common orange boxes.

The crate is almost invariably used in bringing tunas to market on the backs of burros. When intended for immediate market use they are emptied in piles upon the ground, those not exposed for sale being covered with green herbage or old cloths and kept at a lower temperature than the surrounding atmosphere by the evaporation of water sprinkled over them from time to time. Handled in this way they keep in the open air for ten to twenty days.

Some species, the chaveñas especially, in the vicinity of Aguascalientes are regularly kept over winter in the fresh condition, and one may find some of the various species and varieties in the market places during practically the entire year. From late May to early December there are fresh forms constantly found, and even in the spring some of the forms of joconoxtle, which are eaten only after being cooked, may be found upon the trees. However, the majority of those upon the markets after December have been packed. Around

Aguascalientes these are almost invariably chaveñas which have been put in storage. They are spread in thin layers, alternating with layers of straw or old hay in a dry, airy place. Handled in this way they will keep from October or November to the 1st of May.

MACHINERY USED IN MAKING TUNA PRODUCTS.

It is scarcely necessary to state that all of the appliances used in the manufacture of tuna products are of the most primitive nature, simple and crude but often exhibiting a great deal of skill and ingenuity in the use of inexpensive materials at hand which might not be recognized as at all suitable by people accustomed to the use of machinery. It must be remembered that the processes described here are essentially those of the primitive peoples of the Republic of Mexico. They are processes which have been followed in all essential particulars since Cortez first landed, and how long before no one knows. It is said that the same processes are in vogue to-day as then, with but slight modifications.

It is a common practice for a suitable number of people to establish a camp in the prickly pear thickets late in the season for the purpose of manufacturing queso and the other products. A factory and a few rude huts are quickly thrown up, giving shelter to the workers as well as to the manufactured products. We have seen factories consisting of a small adobe building of one room about 25 feet long by 15 feet wide, thatched with the leaves of the yucca (Pl. V, fig. 1). They usually contain one or two kettles, generally of copper, although pottery is sometimes used, one or two troughs hewn out of willow, three or four earthenware tubs, and smaller earthenware vessels in which the liquids and plastic materials are handled. The kettles are set in the ground up to their handles, on a slightly elevated side of the room, over a rude furnace consisting of earth, rock, and adobe. Besides the kettles, there are in the rear of the room two seeders of tin, supported upon a frame. On the left of the factory is a large trough hewn from the trunk of a willow, and in the rear of the room is another smaller one of the same material. Under the seeders are earthenware tubs. The bottom of an olla (earthenware urn) projects above the first kettle. The kettles are reenforced to a height of about 18 inches by slabs of wood cut from the trunk of a large yucca. These are tightly fitted together and the whole tied with a rope made of agave fiber. Some of the yucca wood is macerated and used to chink in around the top of the kettle to make it tight. The kettles are about 20 inches deep and 3½ feet in diameter.

The seeder consists of a tin vessel with a short conical base having a pivot support in the center to receive an axial shaft upon which are

hung paddle-like wings, shown in more detail in Plate IV, figure 1. This axis with the paddles is operated by a crank, as shown in the illustration. The tin vessel is perforated by nail holes of such size that they will not allow the seeds to pass through.

The furnace is exceedingly crude and consists of a fire pit under the kettles, and somewhere a smoke flue.

TUNA PRODUCTS.

Of the numerous products manufactured from the prickly pear, only those which appear to be the most important have been selected for discussion. To consider all of the products would necessitate the use of more space than can be devoted to the subject. Those enumerated will give a very fair idea of the importance of the crop upon the highlands of Mexico.

In detailing the methods of manufacture it is realized that the descriptions given constitute simply the recipe used by the people in a certain locality. There may be variations in the methods employed in different sections, but the essential features of the processes do not differ. The methods here outlined are those employed in the vicinity of Villa Garcia, in the State of Zacatecas.

The tuna products are usually manufactured in the season when the fruit is thoroughly ripened. At any other time the business would not be as profitable; the labor of collecting would be much greater if done while the crop was only partially ripe. Again, there is less need for preservation of the valuable material so long as it remains in good condition upon the trees and may be eaten in the fresh state.

In the different manufacturing processes all available tunas may be used indiscriminately, but there are certain characteristics essential in certain products. Although the pickers usually gather all fruits of whatever species they can find, the prevailing material will be of one species usually best suited to the process.

The tunas may be divided into two great classes, based upon their condition when ripe. One group or class has pulp which when squeezed through a fine cloth gives a limpid liquid with most of the solid constituents in solution. To this group belong the more important of the mansas or cultivated forms, such as the amarilla, the naranchada, the blanca, the palo altena, the fafayuca, the camuesa, the ranchera, and the morada. The other class has fruits whose pulp when treated in the same manner yields an opaque liquid having much solid matter in suspension in a fine granular condition. The foremost of this group is the cardona, and with it should be classed the tapona, the agua-mielilla, the lionera, the pachona, and the opalilla. For the manufacture of queso, melcocha, and miel only those forms

are used which have solid or semisolid substances in suspension in their extracted juices. The members of the other group are more often used for drying.

Colonche may be manufactured from almost any of the species, but as a matter of fact it is seldom made from the mansas, because of the higher value of the fresh fruit. In practice, the species used in a locality is quite constant and the products manufactured are very pure, for one species usually predominates to such an extent as to necessitate its use to the exclusion of others. For instance, in the vicinity of San Luis Potosi and Aguascalientes the cardona predominates, while farther south the lionera, the agua-mielilla, and the artona are more prevalent. It is not economical to prepare the products from the large mansa forms until late in the season, and then they are usually dried. They command a better price when fresh, because the supply is rather limited.

Different colored species produce food products of different colors, as would be expected. The color for a given product from any species, however, may or may not be constant, for the process of manufacture may vary to such an extent as to change the color. This applies especially to such products as miel, melcocha, and queso, which have a somewhat complicated process of manufacture, are subjected to a considerable heat, and, in the case of the last especially, are modified by aeration and kneading after the boiling ceases. The boiled paste from the tuna cardona is almost black, and melcocha is consequently of the same color, but the queso is light brown. The tuna cardona, on the contrary, retains its red color through the boiling process and therefore makes red queso, which does not seem to be in much favor.

When tunas are gathered for manufacturing purposes, the pulp—the part ordinarily used—is removed in the field, as described elsewhere. On account of its exceedingly juicy nature it is gathered in earthenware vessels, or ollas, and taken into the factories in quantities of 50 to 75 pounds. The picker usually has the earthenware vessel strung across his shoulders by means of ropes of maguey (Agave) fiber. When the vessel is filled, it is delivered to the factory in a cart or the picker carries it if the factory is not too far away. Material delivered to the factories consists of the seedy pulp which is ready for the kettles or the seeders.

Analyses of several kinds of tuna products are given in Table III.

TABLE III.—*Analyses of some tuna products.*

Laboratory No.	Name of product.	Total solids.	Soluble solids.	Total proteids (N×6.25).	Water-soluble proteids (N×4.25).	Acids expressed as H_2SO_4.	Polarizations.		Temperature.	Sucrose by polarization.	Sucrose by reduction.	Total sugar as dextrose (Allihn).	Ash in soluble solids.	Alkalinity of ash as K_2CO_3.
							Direct.	Invert.						
		P. ct.	P. ct.	P. ct.	P. ct.	P. ct.			°C.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
2356	Dried tunas (tunas pasadas)[1]	92.54	81.58	2.52	1.20	2.34	− 6.00	− 7.00	22	0.75	1.18	51.06	4.45	.....
[2]2357	Melcocha	86.64	84.46	2.41	1.28	0.54	+ 6.40	+ 5.80	26	0.46	0.00	63.35	4.70	1.24
[2]2357	Melcocha[3]	77.89	.....	.....	.....	.....	+ 4.20	+ 2.00	30	1.55	.....	64.16	.....	.....
[2]2358	Miel	68.98	68.65	3.06	1.19	0.26	+ 7.00	+ 4.50	22	1.88	0.00	61.47	1.19	0.62
[2]2359	Queso de tuna[4]	91.56	89.06	2.55	0.53	0.44	+14.00	+14.00	17	0.00	0.10	55.39	3.64	1.66
[2]2360	Queso de tuna[5]	86.09	83.87	2.22	1.21	0.51	+10.00	+ 9.00	22	0.75	0.10	55.48	2.96	1.66
2361	Concentrated pulp of Opuntia laevis (?)[6]	.....	.....	.....	.....	.....	.....	.....		.....	0.48	51.60	.....	.....

[1] Percentage of seed, 24.50. This was prepared from the tuna amarilla.
[2] Manufactured from the tuna cardona.
[3] Analyses made by Bureau of Chemistry, United States Department of Agriculture.
[4] Large sample from Hacienda Los Campos.
[5] Small sample from public markets at Aguascalientes.
[6] See page 62.

MIEL DE TUNA.

In the manufacture of miel de tuna the seeder is usually not employed. The peeled tunas are put in the kettles and boiled until the free seeds fall to the bottom. This requires usually about two hours, fresh material being added from time to time as the water evaporates. The seeds are removed with a sieve and the sirup is returned to the fire and boiled slowly for two or three hours more, or until it approaches the consistency of honey. It is then poured into wooden troughs, where it is thoroughly stirred with wooden paddles until completely cooled. After setting for twelve to twenty-four hours it is packed away in bottles or earthenware jugs. It may be kept about the same as molasses and is said to remain in good condition indefinitely. After a time, however, it candies and becomes difficult to handle.

The method of cooling is considered very important in the manufacture of this product as well as in the manufacture of melcocha and queso, for if the material is allowed to cool without stirring it is believed to have a tendency to sour. After it has cooled there is said to be no further danger of deterioration. The only change which appears to take place thereafter is crystallization, which begins rather soon and is said to continue for about two years, until a completely candied mass is formed. Upon the large haciendas away from the towns this sells for from 15 to 20 cents a liter (about 1 quart).

MELCOCHA.

In the manufacture of melcocha peeled tunas are put in the machine and seeded. The kettles are filled two-thirds full of juice, which is

boiled upon a brisk fire for about three-quarters of an hour, when more juice is added and the boiling continued. The foam arising from the boiling is very great when the sirup is thin, but as it thickens this becomes less; then more of the fresh juice is added to thin it until, little by little, the supply is all used up. This takes four or five hours in all. The material is then kept warm by banking the fire. After this it is kept in such a condition that it thickens very gradually for one or two hours more, the object now being to keep the evaporation constant and low until the proper consistency is reached. When a spoonful can be dipped up and the material will not run out when turned upside down, the process of evaporation is stopped and all fire is removed from the furnace.

The process of the manufacture of melcocha is exceedingly variable. The one detailed above is that interpreted to us by Señor Enrique Guerra in 1905. In 1906 other persons upon the same hacienda prepared melcocha somewhat differently.

Invariably the puddled paste from which queso is made is called melcocha also, and often this is preserved for future use with no kneading or other preparation except packing away in suitable receptacles, as described elsewhere. The only difference between melcocha and queso in that case consists in the kneading and puddling which the paste gets after being cooled, the melcocha being simply unkneaded queso. The two products might be likened to taffy in the different stages of its manufacture, the taffy corresponding to the queso and the cooled sugar or molasses before being pulled to the melcocha.

After the evaporation is stopped, the melcocha is poured into a trough, as in the case of miel, and worked with wooden paddles very rapidly in order that it may cool as quickly as possible. When the temperature is reduced so that it is not uncomfortable to the touch, the vessel is covered and left until the next day, or it may be left two or three days. The best way, it is said, is to puddle upon a stone or wooden table twenty-four hours after evaporation has discontinued. The rule here is to "strike" the "dough" 100 times on a stone, the whole lump being raised above the head and then dropped forcibly 100 times. During this process flavoring matter, almonds, etc., are sometimes added to the product, but usually nothing is added to the concentrated juice.

Crystallization begins in melcocha within a month or six weeks after manufacture and continues indefinitely, the material becoming more and more candied with time, like miel.

Melcocha may be kept in earthen jars with wide mouths, which is the common method of preservation. A poorer way is to preserve without puddling. In this case, about two tablespoonfuls are put in a

corn husk and covered completely and as tightly as possible with this kind of covering. In this form it is a common article upon the market places in the larger cities, and this quantity usually sells for 1 cent. The price of melcocha put up in quantity in earthenware jars is from $1.50 to $2 per arroba (25 pounds).

QUESO DE TUNA.

The queso, or cheese, of the tuna is made the same as melcocha, except that the evaporation is carried a little further or until the cooled material will not leave the spoon when it is shaken. The puddling is also more thoroughly done. The rule here is to "strike" 150 or 200 times upon a flat stone or wooden table. Queso, while so similar to melcocha, never crystallizes, although the evaporation is carried but little further.

After puddling the product is put in any shape desired. It is commonly shaped in small hoops of white pine or willow about 3 inches in diameter or in larger boxes dovetailed at the corners so they can be removed in pieces. The first method gives the product the form of the common cottage cheese found upon the markets, and it is from this that it receives its name queso de tuna, or cheese of the tuna. These molds are moistened just before the material is packed into them to be shaped. They are then removed immediately. The queso sets perfectly in from one to two hours. It is a common practice at the larger haciendas, where a first-class product is desired, to cover the queso with tin foil to preserve the color and prevent evaporation. No other changes appear to take place in this product.

Queso will keep indefinitely if put away in a dry place to prevent molding. However, it gets harder and harder from loss of moisture as time goes on. Covering with tin foil delays hardening and prevents darkening to some extent. The more puddling or kneading the material gets in its manufacture the harder it becomes and the lighter is its color. To avoid the labor of puddling, it is a common practice to get rid of the natural dark color by adding dyes. This leaves the queso soft and gives to the trade the color that is pleasing. Beet, carrot, and other vegetable juices are used for this purpose.

Sometimes one will find queso and melcocha packed in vessels in alternate layers. After a few months the melcocha is candied to a considerable extent, while the queso remains soft and plastic, giving what is considered a very desirable product.

The treatment of the paste after leaving the kettles is one of aeration and apparently does not differ essentially in effect upon the product from the process of pulling taffy. Although it would seem that the details of the process might be quite varied, wherever the writers have seen queso puddled the method has always been the

same. A batch of the paste consisting of 10 to 20 pounds is placed upon a flat rock which has been previously moistened with water. The paste is gathered into a compact mass by hand and the whole raised above the head of the operator and dropped, or really thrown forcibly down upon the rock again. The edges of the flattened mass are gathered together again and the process is repeated many times. Usually two persons work by turns, for the labor is very exhausting, the mass of paste being quite heavy and the movements necessary to handle the mass properly being rapid and vigorous.

COLONCHE.

In the preparation of colonche, which is a fermented drink, the pulp, including the seeds, is boiled slowly two or three hours, fresh material being added from time to time as evaporation goes on. The whole mass is then strained and the liquid set away to cool. Usually a little old colonche is added to start fermentation. This beverage is used from the time fermentation begins up to twenty days or more thereafter. The longer it stands the more violent is its intoxicating effect. In some cases the seeds are removed by the seed extractor and the juice is boiled, as before. Sometimes, but not so often as formerly, old colonche is distilled into an alcoholic beverage.

It was a common practice a few years ago to distill the fermented peelings of the tuna, but the practice has not been successful because of the ill effects which the product is said to have. The natives say it produces violent headaches, and for this reason it has been almost entirely supplanted by mescal, tequilla, and other maguey (Agave) products which produce less deleterious effects.

No successful method seems to have been devised for the preservation of colonche. Some have tried to bottle it, but without success. It is quite probable that the fresh juice could be preserved by boiling, thus killing all germs, and then hermetically sealing it in vessels in much the same way as fresh fruits are preserved in this country. The failures appear to the writers to be due to imperfect methods of sterilization.

RELATION OF TUNAS TO FINISHED PRODUCT.

It is seldom that one, by talking to the men who make the queso, can get any idea of the amount of boiling and evaporating to which the tuna juice is subjected. Fortunately, in 1906, an opportunity was had to visit Los Campos in season. Through the kindness of Señor Enrique Guerra a day was spent at a queso factory and notes were secured upon the work carried on that day, including the entire process from the charging of the kettles in the morning to the puddling in the evening. The next morning the weighing and kneading of the paste were also witnessed.

At 6 o'clock in the morning of the day spent at the factory the kettles were charged with 65 gallons of the juice of the tuna cardona, a portion of which had been seeded the night before. A brisk fire of wood of the same species of prickly pear was started at the same time. During the day 25 gallons more of the juice were added as evaporation proceeded. The evaporation was carried on very slowly and somewhat irregularly until 8 o'clock in the evening. But little attention was paid to the kettles until toward evening, when the juice was constantly stirred. The juice was secured from 150 gallons of peeled tunas from which the rind had been completely removed, the shrinkage in seeding being very largely due to the bulky seed. These, however, it was impossible to weigh. The melcocha, which was kneaded into queso the next day, measured 12 gallons and weighed 130 pounds. These figures are sufficiently exact for ordinary computations upon these processes.

The relation of rind to pulp and seed in the tuna cardona as determined by our laboratory investigations is as 42.66 to 57.34. In the above charge of the kettles, therefore, the tunas, if they had been picked in the field, rind and all, would have measured about 261.66 gallons, yielding 150 gallons of tunas with the rind removed, which when seeded gave 90 gallons of juice. This when boiled gave 12 gallons of queso, as previously stated.

These figures apply only to the tuna cardona. The proportions might be very different for another species, but the amount of queso prepared from any other species is small. The cardona is preeminently the tuna for the manufacture of queso. It is a native species of average size, weighing about 1½ ounces. It is only one-half to one-fourth the size of many of the cultivated forms.

DRIED TUNAS (TUNAS PASADAS; TUNAS SECAS).

The native Mexican exhibits a great deal of dexterity in the use of the knife in the preparation of the tuna to be dried. The thin outer skin of the fruit is so impervious to moisture that evaporation does not take place rapidly, and the fruit dries very slowly until this skin is removed. At the same time, because of the small amount of pulp and the large amount of juice, it is not a good plan to slice the fruit as apples are sliced. The plan followed is to peel very thinly and dry the pulp and rind intact. The tuna to be peeled is grasped with the thumb and middle finger of the left hand and with a sharp knife the epidermis is literally whittled off in small pieces almost as thin as paper. The operator saves all of the rind he can, taking off only the thin, hard epidermal covering, together with the areoles containing the spicules. The flower scar is left unmolested to dry upon the fruit. When peeled the fruits are sun dried upon a latticework of switches tied together with maguey (Agave) fiber or narrow strips of raw-

hide (Pl. III, fig. 2). The drying occupies from ten to fifteen days, when a yellow deposit, consisting probably in large part of crystals of dextrose incased in a covering of gum, plant mucilage, and possibly some uncrystallizable levulose, completely covers the outside of the fruits. They are then packed in woven rush bags, and in this condition are said to keep quite as well as other dried fruits. An attempt is made to get the outside thoroughly dried, but there is a great deal of moisture left in the pulp. After being packed loosely in a box for six months the pulp is still quite pasty and on the whole little drier than fresh dates as ordinarily found upon the markets. When kept in large quantities, tightly packed, the evaporation is, of course, not as great.

Considerable dexterity is exhibited by the operators in preparing the tunas for drying. The writers had the good fortune to observe the process in Montesa in the State of Zacatecas. Plate III, figure 1, tells better than words the attitude of the operator in peeling tunas. The fruit is held between the thumb and middle finger of the left hand, the thumb resting on the flower scar, and with a sharp knife in the right hand the epidermis is whittled off. The movements, contrary to what one would expect, are comparatively simple, the right hand moving the knife rapidly in one plane, the left holding the tuna between the thumb and middle finger, the index and third fingers rolling it on its axis. It makes two revolutions before it is completely divested of its epidermis. During the first revolution the epidermis is removed from the upper portion; then the fruit is tilted slightly as it revolves slowly, and the epidermis is removed from the lower half during the second revolution on its axis. The epidermis is thus removed in small very thin pieces. Before being peeled the fruit is brushed to remove the spicules. The operator shown in Plate III, figure 1, was timed repeatedly to determine the speed at which he worked. A fruit was peeled with from 28 to 35 strokes of the knife and in the remarkably short space of ten seconds.

At times a small stick about the size of a lead pencil is thrust into the proximal end of the tuna after it is peeled. It is then squeezed between the fingers to express as much of the juice as possible. This shortens the drying period three or four days, but much valuable material is, of course, lost, and the product prepared in this way is of inferior quality.

Cartons in which the dry tunas are packed contain about an arroba (25 pounds), or 600 dry tunas, for which the producer realizes from $1.50 to $2.50, depending upon the character of the crop.

Usually dry tunas are prepared from the white and yellow mansa forms, such as the amarilla, the naranjada, the fafayuca, the palo altena, the blanca, the teca, etc. The wild forms, such as the car-

dona, the pachona, the agua-mielilla, etc., are too small and contain relatively more spicules, both of which characters are objectionable. Again, the red species dry almost black and are consequently not nearly as attractive in the finished product as the lighter colored varieties.

METHODS USED IN ANALYSES OF TUNAS.

The methods of analyses which were used in this work are for the most part those of the Association of Official Agricultural Chemists.[a] In some cases the nature of the work seemed to demand a modification of these methods, and the scheme as used in the laboratory for the determination of each constituent is briefly outlined below.

(1) *Average weight.*—Weigh eight or ten average-sized fruits and divide the total weight by the number taken.

(2) *Percentage of rind.*—Remove the rind from the fruit by cutting off each end just through to the pulp, then cutting once lengthwise through the rind to the pulp, and then peeling back the rind. A distinct division usually exists between pulp and rind, rendering their separation easy. Calculate the percentage from the average weight of the rind and fruits taken.

(3) *Percentage of seed.*—With the hands squeeze the pulp obtained by the method explained in the preceding paragraph through a piece of stout, thin muslin. By this means practically all but the seed is forced through the meshes of the cloth. After washing with water, dry the seed on the water bath and weigh. Calculate the percentage from the average weight of the seed and fruits taken.

(4) *Percentage of refuse.*—The percentage of total refuse represents the sum of the average weight of seed and of rind divided by the average weight of fruits taken.

(5) *Percentage of edible portion.*—The difference between 100 and the total refuse represents the edible portion.

(6) *Percentage of total solids.*—Place 20 grams of the fresh pulp obtained by process No. 3 in a flat-bottomed dish which contains from 4 to 5 grams of freshly-ignited asbestos. Dry to constant weight in a water-jacketed vacuum oven at 70° C., and calculate the total solids.

(7) *Insoluble solids.*—Use Kremla's method as modified and described in Bulletin No. 66 of the Bureau of Chemistry, page 13.

(8) *Specific gravity of the juice.*—Filter some of the pulp obtained by process No. 3 through a piece of thin cloth, and determine its specific gravity by means of a Westphal balance. Determine the total solids of the juice from its specific gravity by the rules given in Bulletin No. 65 of the Bureau of Chemistry, Table IV, page 32.

(9) *Total nitrogen.*—Determine the nitrogen in 10 grams of fruit by the Kjeldahl method. The results obtained are used for the calculation of amids. The total proteids are the sum of the albuminoids and amids.

(10) *Albuminoids.*—Determine the albuminoid nitrogen in 10 grams of the fruit by the method of Stutzer as given in Bulletin No. 46 of the Bureau of Chemistry, revised edition, page 24. Multiply the nitrogen by 6.25 for the albuminoids.

(11) *Amids.*—Subtract the nitrogen of the albuminoids from the total nitrogen, and multiply the remainder by 4.25.

(12) *Acids.*—Take from 10 to 30 grams of the pulp, or better 100 c. c. (10 grams) of filtrate from the insoluble solids obtained by process No. 7, and titrate with N/10 potassium hydroxid. When the juice is highly colored its own coloring matter will serve as an indicator of the end reaction; otherwise use phenolphthalein or cochineal (calculate to per cent H_2SO_4).

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[a] U. S. Dept. Agr., Bureau of Chemistry, Buls. 65 and 66.

(13) *Polarization* (*direct*).—Weigh 26.048 grams of the fruit, transfer to a 100-c. c. flask, add 50 c. c. of water, from 3 to 5 c. c. of subacetate of lead, and about 10 c. c. of alumina cream to clarify. Make up to volume; then filter and polarize.

(14) *Polarization* (*invert*).—In a flask graduated to 50 and 55 c. c., place 50 c. c. of the clear solution prepared in accordance with process No. 13. Fill to the 55-c. c. mark with concentrated hydrochloric acid. Place the flask in the water bath and heat until the thermometer marks 68° C., requiring fifteen minutes in the heating. Remove and cool to room temperature; then polarize and note temperature. Calculate the percentage of sucrose by Clerget's formula, $S = \frac{(a-b)\,100}{144-\frac{T}{2}}$

(15) *Reducing sugars*.—Take 25 c. c. of the solution prepared for polarization as explained in process No. 13 and add sufficient sodium sulphate to precipitate the excess of subacetate of lead; then filter. Take an aliquot part (5 c. c.) of this filtrate containing not over 0.2 gram of reducing sugars, add to a beaker containing 25 c. c. each of Soxhlet's copper and alkaline tartrate solutions, and make volume about 100 c. c. with water. Heat the contents of the beaker over wire gauze with the flame so regulated that boiling begins in four minutes. Continue boiling for exactly two minutes, keeping the beaker covered with a watch glass. Without diluting, filter the cuprous oxid at once on a weighed asbestos felt in a Gooch crucible, using suction. Wash thoroughly with distilled water at 60° C., then with 10 c. c. of alcohol, and finally with 10 c. c. of ether. Dry for thirty minutes in a water oven at 100° C., cool in desiccator, and weigh as Cu_2O. Calculate sugars as dextrose from Allihn's table. Make correction for spontaneous precipitation of cuprous oxid.

The asbestos used is specially prepared by digesting with 1 to 3 hydrochloric acid for two or three days. Wash free of acid and digest for a similar period with a soda solution, after which treat for a few hours with hot alkaline copper tartrate solution of the strength employed in sugar determinations.[a] The asbestos is then washed free from alkali, finally digested with nitric acid for several hours, and after washing free from acid it is shaken up with water for use.[b]

(16) *Sucrose by reduction*.—Invert the same amount of solution described in process No. 13 as was used for reducing sugars, using hydrochloric acid in the same proportion for inversion as described under process No. 14, and invert in a similar manner. Neutralize with sodium hydroxid and determine total sugars as dextrose. Subtract from this the reducing sugars obtained by process No. 15 and multiply the difference by 0.95 for sucrose by reduction.

(17) *Ash in soluble solids*.—Treat 50 c. c. of the solution obtained by process No. 6, as outlined under Determination of Ash in Bulletin No. 66 of the Bureau of Chemistry, page 13.

(18) *Alkalinity of ash*.—Add in known amount an excess of N/2 hydrochloric acid to the dish of ash obtained by process No. 17. Add 1 c. c. of cochineal solution and titrate with N/10 potassium hydroxid. Calculate to K_2CO_3. One c. c. N/10 KOH= 0.00691 grams K_2CO_3.

(19) *Alcohol precipitate—vegetable mucilage, pectin, and salts of organic acids*.—Determine by the method given in Bulletin No. 66 of the Bureau of Chemistry, page 21.

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[a] Reducing sugars were calculated to dextrose in this work because an excess of dextrose over levulose appeared to be present in the tunas. Since the reducing power of dextrose in terms of other reducing sugars is known, these values can be converted into any form of reducing sugars desired by means of their dextrose ratios as given by C. A. Browne, jr., in the Journal of the American Chemical Society, Vol. XXVIII, No. 4.

[b] Munson and Walker. Journal of the American Chemical Society, Vol. XXVIII, No. 6, p. 666.

COMPOSITION OF TUNAS.

TOTAL SOLIDS.

The solid matter in the fruit is about the average of that found in other fruits, as may be seen by comparing Tables IV and V.

Like all other fruits, the quantity of solids differs for the different varieties, amounting to from 5.33 per cent in No. 6, San Antonio, *O. lindheimeri*, to 11.60 per cent in No. 8057, tuna amarilla. No. 5, Agricultural College, had a higher solid content than the latter, but is not comparable with the other fruits, because it is an Echinocereus, and the seeds were included with the other solids, they being edible in this group of the plants.

The amount of total solids in any fruit is not necessarily an indication of its value, though usually high solids indicate high soluble solids and a high sugar content, and the nutritive value of any fruit is dependent on the quantity of these. Since the solids of the tuna are practically all soluble in water and a large percentage of the soluble material is sugar, the percentage of total solids of this fruit is usually an index of its nutritive value, but this is not always the case. No. 5, San Antonio, for example, had 7.13 per cent of solids, but only 1.41 per cent of these solids was sugar. However, with most tunas, practically all of the total solids of the pulp exclusive of seeds are soluble, and a high percentage of the soluble portion is sugar. There are few fruits that will make as good a showing as the tunas in this respect. In many of the small-seeded fruits, like figs and strawberries, the seeds are included in the total solids, while in the others, like apples and pears, there is a large amount of marc,[a] and both the seed and marc being insoluble there is a large difference between the total and soluble solids. In the total-solids determinations of the tuna the seeds were not included and the marc is exceedingly small in quantity, as may be seen by taking the difference between the total and soluble solids.

The total solids of the juice is calculated from its specific gravity. This determination should be about the same as the soluble solids and total sugars. Where the sugars are more than the soluble solids or the total solids of the juice, there is probably some error in soluble solids determination. The per cent of total solids of the juice is quite often higher than the soluble solids, due no doubt to the fact that some pulp was in the juice when its specific gravity was taken.

Almost without exception the fruits from Mexico contain more solids and sugar than those varieties native to the United States.

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[a] Material insoluble in water.

Composition of edible portion.

Water-soluble proteids ($N \times 4.25$).	Acids expressed as H_2SO_4.	Polarizations. Direct.	Invert.	Temperature.	Sucrose by polarization.	Sucrose by reduction.	Total sugars as dextrose (Allihn).	Total ash.	Ash in soluble solids.	Alkalinity of ash as K_2CO_3.
Per ct.	*Per ct.*			°C.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
....	0.850	−1.20	−1.70	30	0.38	0.00	3.87	....	....	....
0.284	0.470	−0.10	−2.00	28	1.46	0.93	9.03	....	0.50	0.400
....	0.950	+1.00	−1.20	30	1.65	1.97	5.98	....	....	....
0.220	0.220	−1.00	−1.00	28	0.00	0.13	7.51	0.69	0.59	0.538
	0.320			....	....	0.88	3.94	....	....	....
....	1.580	±0.00	±0.00	30	0.00	2.60	3.35	....	....	....
0.252	0.742	−0.27	−1.18	29	0.70	1.09	5.61	0.69	0.55	0.469
0.163	0.570	+0.80	+0.80	30	0.00	0.00	4.18	0.81	0.58	....
0.260	0.070	+3.70	+3.70	30	0.00	0.00	9.44	0.74	0.63	....
0.193	0.060	+0.30	+0.30	29	0.00	0.00	8.87	0.42	0.89	0.090
0.223	0.047	+2.30	+1.80	29	0.38	0.00	7.82	....	0.98	0.083
....	0.137	....	....	....	....	....	8.36	....	....	....
0.226	0.099	....	....	....	....	0.56	9.49	....	1.20	0.236
....	....	....	....	....	....	....	8.22	....	....	....
0.167	0.156	....	....	....	....	0.77	8.66	....	0.18	....
0.221	0.322	....	....	....	....	0.00	4.76	....	0.90	0.408
0.107	0.690	....	....	....	0.40	0.66	7.11	....	0.71	0.620
0.100	0.316	....	....	....	0.50	1.19	7.37	....	0.78	0.440
0.184	0.247	+1.78	+1.65	29.5	0.21	0.13	7.66	0.66	0.76	0.313

of fruit.
g whole fruit in potato shredder.

TABLE V.—*Comparative analyses of different fruits.*[1]

Name of fruit.	Variety.	Weight.	Refuse.	Edible portion.	Composition of edible portion.												
					Total solids.	Soluble solids.	Specific gravity of juice.	Total proteids (N×6.25).	Acids as H_2SO_4.	Polarizations.		Temperature.	Sucrose by polarization.	Sucrose by reduction.	Total sugars, as invert.	Ash.	Alcohol precipitate.
										Direct.	Invert.						
		Grams.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*			°*C.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Pear	Eastern Bartlett	120.00	25.00	75.00	16.97		1.060	0.360	0.146						8.26	0.310	
Apricot		62.40	6.00	94.00	14.34			1.250	0.833						11.10	0.508	
Blackberry					12.69	7.24		0.919	0.638	− 1.10	−1.00	18	0.16		4.83		0.681
Cherry			5.32	94.68	12.64	10.60		0.650	1.627	+ 0.20				0.00	6.84	0.602	0.668
Banana	Johnson		34.90	65.10	26.13	21.78		1.250	0.333	+11.30	−6.38	27	13.83	11.73	21.71	0.848	
Fig	California				20.13			1.344	0.119						15.57		
Orange	Florida navel	160.00	26.30	73.70	13.11			0.330	0.686	+ 2.00	−2.50	18	3.33		7.29	0.610	
Currant					12.97	6.07		1.369	1.546	− 1.40				0.00	3.44	0.470	0.804
Peach	Elberta		8.07	91.73	15.23	13.28			0.440	+ 7.25	−2.20	27.4	7.39	7.19	9.60		
Do	Average of seven varieties	71.66	7.71	92.29	14.45	11.87		0.350	0.560					5.87	7.57	0.520	
Apple	Baldwin	180.00	25.00	75.00	13.77		1.075	0.520	0.376	− 2.20	−3.60	18			8.26	0.264	
Watermelon			58.00	42.00	7.10			0.300						1.92	4.33	0.370	
Tuna	Average of Nos. 8099, 8485, 8142, 8140.	113.00	41.75	58.25	12.96	12.85	1.048	0.413	0.037	+ 1.90	+1.50	26	0.31	0.15	[2] 11.20		0.250
Do	Average of 27 samples	71.17	56.18	42.26	11.74	11.42	1.044	0.377	0.080	+ 1.05	+0.78	27	0.17	0.22	[2] 9.94	0.44	0.242

[1] In compiling this table the analyses were taken from various sources, but they will be found principally in—(a) Buls. 66, 87, and 97, Bureau of Chemistry, U. S. Dept. Agr.; (b) Bul. 28, Office Expt. Stas., U. S. Dept. Agr.; (c) Repts. Cal. Agr. Expt. Sta.; (d) Rept. Mass. Agr. Expt. Sta., 1889. Incomplete analyses of some of the fruits have been in some cases added to from other sources.

[2] These figures were obtained by dividing the dextrose (10.73 and 9.53) by 0.958, the dextrose ratio of invert sugar. See page 31.

PROTEIN.

The proteids are a group of bodies found in greater or less quantity in all foods, but the amount found in any fruit is usually quite small. Bananas, figs, currants, and apricots have been found to contain over 1 per cent of proteids, but as a rule fruits have less than 0.5 per cent. This is true of the tunas, which average about the same as the pear, the apple, or the peach.

Protein alone can furnish material for building flesh or muscle in the animal body. A man of moderate work will require as much as 1 pound of protein for every 6 pounds of carbohydrates eaten. If the fruit of the prickly pear should have 0.5 per cent of protein and 10 per cent of sugar, and all or equal amounts of both be digested, those Mexicans who make this fruit their exclusive diet would get 20 pounds of carbohydrates for each pound of protein obtained. It is plain to see, therefore, that some other nitrogenous food should be eaten with tunas as with all other fruits to balance the ration.

The proteids are not compounds of definite chemical composition, but they are made up of a group of bodies each differing somewhat from the others in their composition. One element common to all the proteids is nitrogen, but the amount of this element varies in each compound.

The food chemist makes no attempt to separate the various proteids occurring in any food, but he often separates them into two smaller groups of albuminoids and amido bodies, or amids.

ALBUMINOIDS.

The albuminoids are those nitrogenous compounds which more nearly resemble the white of an egg in their composition and function in the animal body. They all contain very close to 16 per cent of nitrogen in the molecule; hence in the method for their estimation in the laboratory the amount present in a food is determined by multiplying the percentage of nitrogen which they contain by the factor 6.25, which has been used in all of the calculations of albuminoids in the tables.

The albuminoids are the most valuable of all the protein compounds because they are the only ones that can serve as building material in the animal body. In an average of all the Mexican samples the percentage of total proteids was 0.377. Of this amount only 0.107 per cent was albuminoids. Thus it may be seen that, roughly, not one-third of the total proteids of the tuna is in the form of albuminoids, which, of course, means that the muscle and flesh forming compounds of this fruit are less than one-third of the total proteids.

AMIDS.

Amids, the other group of compounds into which the chemist divides the total proteids, are a similar group of nitrogenous compounds that are present in plants, especially in their fruits.

They constitute one of the first products formed by the plant in its synthesis of nitrogen with other elements in forming the more complex albuminoids or they are cleavage products in the decomposition of the latter; hence they have fewer atoms in the molecule and a greater proportion of nitrogen. In these calculations it has been assumed that all the amids in the tunas contain 23.53 per cent of nitrogen and the amount present has consequently been calculated by multiplying the percentage of nitrogen which they were found to contain by 4.25.

The amids are not so valuable a food as the albuminoids. They are probably incapable of serving as building material, but may, like the carbohydrates, serve as fuel. They are also thought in some way to protect and prevent the consumption of proteids of the body tissue.

Because of the comparatively large quantity of amids in the total proteids the amount of the latter in the tunas would not be equal in value to the same amount of proteids in meat or many other nitrogenous foods.

In these analyses the water-soluble proteids have been determined, which no doubt include all of the amids and a part of the albuminoids. This determination was made to ascertain the probable available proteids and partly to serve as a check on the total proteids.

ACIDITY.

A study of the tables giving the analyses of the whole fruit as well as the rind and pulp shows the acid to be exceedingly variable in the different varieties of this fruit. In fact, it was found to be variable in different samples of the same variety, depending, no doubt, upon the ripeness of the fruit.

The amount of acid in the rind varies from 0.13 per cent in tuna amarilla (No. 8057) to 0.96 per cent in tuna chaveña (No. 8100). In the pulp of the Mexican samples there was 0.02 per cent in tuna aguamielilla (No. 8119) and 0.32 per cent in tuna durasnilla blanca (No. 8143).

A much greater percentage of acid was found in those samples collected in the United States, with the exception of the tuna tapona, from California, which had only 0.07 per cent. The average acid in the pulp of the samples from San Antonio was 1.2 per cent, while No. 6, from that place, had 2.15 per cent of acid. The ratio of acid to sugar in these six samples was only 1 to 7.5—enough to give the

fruits a decidedly tart taste. While the acid is not too high the sugar is not in sufficient quantity to make the fruits as desirable as the Mexican varieties. One trouble with the Mexican samples seems to be that the ratio between acids and sugars is too great to give them the requisite tartness. For example, the average acids and sugars of these samples show a ratio of 1 to 119, while even such fruits as the banana and fig have a ratio of about 1 to 70 between their acids and sugars, and in some fruits the ratio is as low as 1 to 5 or 6.

It is of interest to note the large amount of acid, 3.48 per cent, in *Opuntia imbricata*, which is the only sample of a Cylindropuntia included in our list. This fruit contains no sugars and is not edible, but was analyzed because of its high acid content. Few, if any, common edible fruits contain so large an amount of acid. The acids in ripe apples rarely exceed 1 per cent; lemons and limes contain only about 5 per cent of citric acid (calculated as sulphuric).

The amount of acid found in the tunas has been expressed in the tables as sulphuric acid (H_2SO_4), because this is the customary manner of expressing such results. This furnishes a ready means of comparing the relative amounts of acid found in different fruits. The acid in several varieties of the tuna has been separated and determined to be malic acid. There were no volatile acids in any of the fresh samples tested.

SUGARS.

Polarizations.—With very few exceptions all fruits and unadulterated fruit products are levorotatory toward polarized light, but an examination of Tables I, II, and IV will reveal the fact that, while some varieties of the tuna were levorotary, most of those examined were dextrorotary both before and after inversion. This unusual phenomenon has caused the writers to devote some little time to a study of the polarizations of the tuna and some of the preserves prepared from them. While in all probability their dextrorotation is due to a large excess of dextrose over levulose, it is impossible to say definitely that such is the case; in fact, the writers can not say definitely whether the dextrorotation is due to dextrose or to some other sugar or substance. "Miel" and "melcocha," two products from the tuna that are prepared by evaporating the juice to the consistency of honey, have small white wart-like crystals somewhat larger than a pin head scattered throughout the mass. These crystals are not so soluble as the rest of the material, and a 50 per cent solution of alcohol dissolves almost everything else, leaving them in a fairly pure condition. When these crystals are separated they are decidedly dextrorotary, exhibit the phenomenon of birotation, give the cobaltous nitrate test, and have other properties in common with dextrose; but a careful separation and study of the

different sugars of the fruit have not been completed. It is impossible to say just what they are or in what proportion they are to be found in the fruits, but the writers have made double polarizations for each sample and from these data calculated the sucrose by Clerget's formula as well as by reduction.

The probabilities are that the sucrose obtained by polarization, which is as a rule more than that obtained by copper reduction, is too high, the apparently large amount of sucrose having doubtless resulted from the birotary action of the fruits in the reading before inversion, which property was destroyed in boiling for inversion.

For a long time the writers were not aware that the fruits contained sugars that were birotary, and this no doubt explains why considerable trouble was experienced in getting uniform results from the same samples, and even sometimes from the same solutions. For this reason the writers are not sure of the accuracy of many of the polarizations reported in this bulletin. It is clearly shown, however, that most of the fruits and their products are slightly dextrorotary. The sucrose and total reducing sugars have both been carefully determined in each sample by copper reduction, and it is believed that these results are fairly accurate.

The difficulties resulting from birotation in the polarizations of the fruits and products may be seen in the results here given of two samples of miel and one of melcocha. These were all read from a one-fourth normal solution which had been treated with lead acetate and alum cream in the usual manner.

Time of experiments.	Miel No. 1.	Miel No. 2.	Melcocha.
Polarization immediately after solution	+5.6	+3.9	+3.6
Polarization six or more hours after solution	+3.1	+1.8	+2.5

For normal solutions multiply the above figures by 4.

Each of these solutions was read from time to time and its dextrorotation was found to decrease slowly until it reached the last figures given in the table in about six hours, after which it underwent no further change.

By referring to Table I it will be seen that the rind was dextrorotary before inversion in every sample, and after inversion in all but No. 8143 (durasnilla blanca). Another interesting fact concerning the sugars of the rinds of the fruit is that, while they had less reducing sugars, they were often more dextrorotary than the pulp of the same fruit, but there was a greater change in the readings before and after inversion and consequently more sucrose in the rind, for the Mexican varieties at least. The average percentage of sucrose in the pulp of these was 0.17, while for the rind the average

was 0.59. Of all the fruits analyzed that were grown in the United States there was an average of 0.70 per cent of sucrose, while in the Mexican samples there was an average of only 0.21 per cent.

In the analysis of a fruit product it is now customary for the food chemist to report these samples which are dextrorotary as adulterated with glucose. If the tuna or its sugars should ever be added to the products from other fruits sufficiently to cause them to be dextrorotary, it would be necessary to make further tests for glucose adulteration. Since in some localities an enormous yield of the fruits can be produced to the acre on land not well suited to other crops and in a country where labor is cheap, their production for the adulteration of other fruit products is at least an economic possibility.

The large amount of coloring matter, salts of organic acids, mucilage, etc., often makes it very difficult to get a clear solution for reading in the polariscope. The products from the fruits and a few of the fruits themselves had to be treated with both lead acetate and alum cream and at times filtered through animal charcoal when very highly colored.

An attempt was made to remove the coloring matter with sodium hydrosulphite ($Na_2H_2S_2O_5$), but by the use of the reagent alone the writers found that they could not clarify sufficiently. If, however, about one-fourth gram of it was added to a part of the filtrate from the lead acetate and sodium sulphate, it was possible to effectually complete the decoloration. The sodium hydrosulphite reduced the polarizations, however, more than animal charcoal, especially if the solution was allowed to stand a while before reading. This seemed to indicate that the large quantity of sulphur dioxid liberated had some action on the sugars. One sample of miel, after standing until it had lost its property of birotation, polarized at +3.1, but after treating with hydrosulphite and standing for three hours more its polarization was only +2.3.

SUGARS BY REDUCTION.

Under total sugars by reduction in the tables of analyses all the sugars present in the fruits are reported as dextrose. As stated elsewhere, this was done because it was believed that nearly all of the sugar in most of the fruits occurs in this form, rather than as levulose or any other reducing sugar. Sucrose was not often found present, and the probabilities are that often when traces of it are reported it was in fruits that were not thoroughly ripe.

It is customary to report the total sugars in fruits as invert sugar regardless of the kind of sugars present, and in Table V, which is a compilation of the analyses of several fruits from a number of sources,

the total sugars are all reported as invert; but as the copper reducing power is about the same for invert sugar, dextrose, and levulose, the percentages would not differ materially when reported in any of these forms. For further discussion of this point see methods of analysis, page 31.

The percentage of sugar varied a great deal for the different varieties, and, as was to be expected, it varied at times for the same variety, depending, no doubt, upon the season and degree of ripeness.

As previously stated, the only Cylindropuntia analyzed had no sugar; it is doubtful whether the fruits of any of this group contain any appreciable quantity, since none are edible.

The samples from San Antonio, Tex., contained less sugar than those from any other locality; No. 6 had no sugar; No. 3 had only 0.85 per cent. The sample with the largest amount of sugar is No. 8485 (tuna amarilla). This fruit had 11.70 per cent. The sample of this same variety collected in 1905 had 11.07 per cent.

The Mexican samples averaged 9.53 per cent of sugar. The San Antonio samples averaged 2.94 per cent, but No. 2, the highest in sugar from the latter place, had 7.18 per cent. For the six American varieties in which the whole fruit was analyzed the percentage of sugars was 5.61; this it will be seen is more than the average sugar in the pulp of the San Antonio samples, but there are included some that should really be classed with the Mexican samples, since they are cultivated forms of Mexican origin much superior to any received from San Antonio. The average in all of the whole fruits of Mexican samples was 7.66 per cent.

While there was some sugar in the rind of all the samples analyzed, only those that seemed of some probable value were examined. The rind of tuna cardona, No. 8099, and tuna durasnilla (blanca and colorada, Nos. 8143 and 8150) contained more sugars than did the rinds of any of the other varieties.

The products of this fruit which were analyzed contained from 51.06 per cent of sugar in the tunas pasadas to 64.16 per cent in one sample of melcocha.

ALCOHOL PRECIPITATE.

Alcohol precipitate is a term applied to a group of bodies that are precipitated upon the addition of 95 per cent alcohol to the juices of the fruits. Plant mucilage, pectin bodies, and salts of organic acids are among these bodies.

Pectin is that substance which causes the juice to jell when evaporated to the proper consistency, and the object in making these determinations was to estimate if possible the relative quantity of this material present.

The alcohol precipitation in the tuna pulp is considerably less than is obtained from other fruits that are commonly used in the preparation of jellies; the average amount found in all the pulps was 0.29 per cent, while 0.67 per cent is found in the cherry, which perhaps contains about an average quantity for fruits of this character.

The alcohol precipitate of the rind is three or four times that of the pulp. In one sample there was 2.33 per cent, while for all the rinds examined the average alcohol precipitate was 1.29 per cent.

Since the rind contains more alcohol precipitate than an average fruit, one might be led to believe that its juice could be made to jell very readily, but such is not the case. The writers have been unable to make jelly from either the pulp or rind of any of the varieties tested.

A further study of the alcohol precipitate will show that evidently only a very small amount of it, if any, is in the form of pectin. No doubt quite a little of this precipitate is plant mucilage; especially is this true of the rind, which is morphologically the modified stem, and this portion of the plant contains so much mucilage that its juice is very slimy. Yoshimura[a] found this mucilage to be composed principally of galactan. E. F. Ladd[b] states that the mucilage is due to pectosic products, but if such is the case it seems that cooking should cause fruits containing it to jell.

ASH IN ALCOHOL PRECIPITATE.

The amount of ash in the alcohol precipitate has been determined by the writers in the pulp of eight samples and in the rind of three, and the results follow:

Sample No.	Percentage of ash.	
	Rind.	Pulp.
4 (San Antonio)		27.92
8099	40.20	25.10
8135	29.15	26.04
8134		29.16
8136		17.24
8141		24.00
8142		20.34
8146		26.92
8150	51.25	
Average	40.20	24.59

Thus it may be seen that about 40 per cent of the alcohol precipitate from the juice of the rind, and about one-fourth of that from the pulp, is ash.

The amount and character of this precipitate show that something else is precipitated in abundance by the alcohol, together with the

[a] Yoshimura, K. Note on the Chemical Composition of Some Mucilages. Bul., College of Agriculture, Tokyo, Japan, vol. 2, No. 4, pp. 207, 208.

[b] N. Y. Agr. Exp. Sta., Sixth Ann. Rept.

mucilage and pectin bodies, if there be any at all of the latter. Neither of these bodies (pectin and mucilage) would contain so much ash; besides, the precipitate formed would be flocculent in character, whereas in the precipitate from both the rind and pulp there was a decided turbidity, which would indicate the precipitation of salts of organic acids, with possibly some dextrose.

The ashes from the alcohol precipitate are the basic constituents of organic salts of calcium, magnesium, and potassium, and the large amount of these ashes shows that the precipitate is largely composed of organic salts.

STARCH.

The iodine test on the ripe fruits failed to reveal the presence of starch in any of them.

ASH.

The examination of the ash of the cactus fruit has consisted principally in a determination of the amount in the soluble solids. Since nearly all the solids are soluble, the soluble ash is almost equivalent to the total ash. This is seen in the few analyses of total ash recorded in the tables. The average soluble ash in the pulp is 0.29 per cent, which is about the same amount found in apples, pears, or watermelons, and less than is found in the citrus fruits.

As with other plants, the seed of this fruit is quite low in ash, it being in No. 8022, for example, only 0.28 per cent of the whole fruit, which is about the same as is found in the fresh pulp.

The amount of ash in the different parts of the fruit in Nos. 8037 and 8038 is tabulated below:

Part of fruit.	Per cent of ash in sample—	
	No. 8037.	No. 8038.
Rind	1.06	1.40
Whole fruit (pulp and rind)	.74	.42
Pulp and seed	.21	.31

It will be seen that the ash in the pulp and seed taken together is about the same as the average of the pulp alone of all the fruits—0.29 per cent.

The character of the ash is decidedly alkaline. Doctor Bigelow[a] has found this to be true with the ash of fruits generally. The alkalinity of the ash of the pulp calculated to potassium carbonate amounts to 55 per cent of the total ash. The alkalinity of the ash of the rind calculated in a similar manner amounts to 41.18 per cent, while for the whole fruit 48 per cent of the ash is potassium carbonate.

[a] U. S. Dept. Agr., Bureau of Chemistry, Bul. 66.

Very little can be said in regard to the plant food removed from the soil by the tunas until the yield per acre can be determined. The amount of total ash removed by the fruits is very small compared to the amount removed by the stems, which in one instance amounted to 33 per cent of the dried plant.[a] Most of this ash was found to be composed of lime and potash salts, which are in abundance in most semiarid soils, and if so large an amount of these salts is necessary for securing the best results with this plant it will probably never suffer for the lack of them in the Southwest.

It will be interesting to determine whether specimens of this plant that have grown for years in Florida and other parts of the world where there is not such an abundance of soluble salts in the soil continue to have their high ash content. Such is not the case with many other plants, and it is doubted whether the cacti grown in regions of abundance of rainfall will be found to contain so much ash.

The ash is also characterized by a very low content of phosphoric acid. An analysis of the ash from 28 samples of cactus averaged only 1.39 per cent of PO_4, while other plants seldom have less than 4 per cent.

THE SPECIES AND VARIETIES OF TUNAS STUDIED.

TUNA AMARILLA (YELLOW TUNA).

(*Nos. 8057 and 8485.*)

A tall open-branching species 10 to 15 feet high, with a black scaly trunk 8 to 12 inches in diameter; joints narrowly oval, about 7 to 8 by 15 inches, but, of course, variable, bright light green; spicules yellow, not prominent on joints; spines numerous, white, turning to a chalky, mottled, dirty gray, flattened triangular and a little twisted, about 1 inch long, 3 to 15 in number; flower orange, with considerable red in outer segments, giving it a red appearance when closed, style and filaments containing a tinge of red and stigma light green; fruit large, oval to obovate, 2½ by 3½ inches, usually somewhat rough, tuberculate, with greenish rind, becoming reddish yellow on complete maturity, and yellow pulp; formidably protected by large bunches of yellow spicules one-eighth inch long.

Tuna amarilla (*Opuntia* sp.) is a cultivated fruit highly prized by the Mexican people. In addition to the above description, it may be stated that very often the fruit presents a tinge of deep dull red before being cut open, but usually yellow predominates and is decidedly apparent when the fruit is opened. The red coloration is due to streaks of red which run through the rind coincident with the vascular bundles.

Among all the samples of tunas included in our list there is none

[a] See Bulletin No. 60 of the Agricultural Experiment Station of New Mexico.

superior in size and flavor to this one. Of the earlier samples, $4\frac{1}{8}$ would weigh 1 pound, but of the last it required only $2\frac{3}{4}$ to weigh a pound. No. 8485, being the larger of the two samples, had, as was to be expected, less waste material than No. 8057, the smaller one. Especially was this the case when the rind was included in the refuse. There seems to be little or no difference between the two samples other than in size; and a comparison of the analysis of the edible portion of the two will show them to be very similar in composition, although No. 8485 was considerably more mature than No. 8057. The large amount of total solids, soluble solids, and total sugar, together with the high specific gravity of the juice, indicates that this fruit has no superior among the samples included in this study so far as its chemical composition goes. There are few of our highly prized American fruits that will make a better showing in this respect, as may be seen from Table II.

Both samples were found to contain over 11 per cent of total sugars calculated to dextrose. The results showed the presence of very little, if any, sucrose. This was one of the few species that were levorotary after inversion. In fact, the 1906 sample was levorotary to the same degree both before and after inversion.

The rind of this variety is not palatable in the fresh state, and its analysis given in Table I shows that it contains comparatively little sugars (4.09 per cent). Its total solids is high. The refuse material is not so very large compared with that of some of the other varieties, even when the rind is rejected. A comparison of the whole fruit (rind plus pulp) is given in Table III. Since the rind has less nutrients than the pulp, the whole fruit will, of course, have less than the pulp alone.

While the rind of this variety is not eaten fresh, it is one of the varieties used in the preparation of tunas pasadas (dry tunas), which are always dried with the rind left on and subsequently eaten in this form. For this reason separate analyses have been made of the rind and pulp. While the fresh rind has only 4 per cent of sugar, this is greatly increased in the dried rind on account of the large amount of water lost in drying, and the tunas pasadas make a very suitable product for use in cooking in a manner somewhat similar to our dried fruits. A large part of the sugar from the pulp collects on the surface of the rind when dried, and this no doubt helps to make it palatable. The fruits of this variety when dried have over 50 per cent of sugar in the whole fruits.

No. 8057 was collected at San Luis Potosi, Mexico, August 12, 1905.

No. 8485 was collected at Aguascalientes, Mexico, September 10, 1906.

TUNA NARANJADA (ORANGE).

(*No. 8142.*)

The tuna naranjada (*Opuntia* sp.) and the tuna amarilla are really very closely related, but the differences, although slight from a taxonomic point of view, are very constant. The plants, so far as the writers can see, are very much alike in every way, the main difference occurring in the color of the fruit, the pulp of this one being, as the Mexican name indicates, orange instead of yellow. The fruit in both the amarilla and the naranjada is very likely to have its pyriform character accentuated, when the lower portion is flabby and does not contain pulp. Very often this basal portion has a tendency to simulate some of the characters of the joint. Externally this variety is darker colored than the amarilla. Associated with the difference in color of the fruit is often to be found a similar difference in color of other parts of the plant. While size, shape, and color of joints are the same in the two forms, the spicules are somewhat darker in the naranjada, and the same holds true of the flowers.

The fruit is of very fine flavor, somewhat above the average in size, and has a thin rind. The rind is only about one-eighth to three-sixteenths inch thick and constitutes only 32.43 per cent of the fruit. This is one of the fruits in which it was found difficult to separate the seed completely from its pulp by our method of forcing the fruit through muslin, and as a result the total solids are somewhat higher and the percentage of seed a trifle lower than is shown by the analysis. This fruit contains less seed than the majority of the other species. In a number of these undeveloped fruits sterile seeds occur, which suggests a possible gradual disappearance of the seeds through cultivation and selection.

There is 62.57 per cent of edible portion in this fruit, which is more than was found in any of the other tunas analyzed. While, for reasons previously stated, the solids reported in the tables may be slightly low, tuna cardona and tuna amarilla are the only fruits analyzed that had more solids. The cardona had 13.7 per cent of solids, the amarilla 13.56 per cent, and the naranjada 12.92 per cent. The polarization readings on the fruit were +2.1 both before and after inversion, and the total reducing sugars were 9.12 per cent.

Collected at Zacatecas, México, September 20, 1905.

TUNA CAMUESA (PIPPIN, APPLE).

(*No. 8140.*)

A tall open-branching plant 8 to 12 or 15 feet high, with a black, bare, scaly trunk 8 to 12 inches in diameter; joints obovate to ovate, very large, in proportion of 8 by 14 inches in last year's growth, bright dark green, areoles obovate for the most part; spicules yellow and commonly formidable even on the joints; spines usually infrequent

and often absent entirely, but sometimes 1 to 3 in number, never very prominent, white, with translucent, bone-like tips; fruit large, obovate, often 2¾ by 3½ inches, dull red, with comparatively thin rind, which is greenish red or streaked and mottled; pulp red and easily separable from the seed.

The tuna camuesa, *Opuntia larreyi* Weber(?),[a] is one of the finest of the cultivated Mexican varieties and belongs in the *Opuntia ficus-indica* group. When the rind is removed, leaving the pulp intact, the latter has a distinct orange cast. When broken open, it is mottled yellow and red, but becomes deeper red with full maturity. It is one of the most palatable of these fruits and has comparatively few seeds, which, of course, is a decided advantage. Oftentimes one-half or two-thirds of the seeds will be found aborted. This has been found to be the case in specimens collected at Los Campos, Aguascalientes, San Luis Potosi, and Zacatecas.

The fruits averaged 163.84 grams each and were the largest of all the samples except those of tapona from Riverside, Cal., which weighed 210.6 grams, and the 1906 sample of amarilla, which weighed 164 grams, or practically the same as the weight of this fruit. These have much fewer seeds than any of the other fruits and a comparatively thin rind, which with the seeds makes a total waste of 43.94 per cent. There is 11.9 per cent of total solids in the edible pulp, nearly all of which is soluble. Acid is present in very small amount, 0.031 per cent. The juice is levorotary to the same degree both before and after inversion, indicating an excess of levulose and no sucrose. The total sugars as dextrose amount to 11.05 per cent.

Collected at Zacatecas, Mexico, September 19, 1905.

TUNA MANSA MORADA (MULBERRY COLORED).

(No. 8039.)

A large open-branching tree with huge joints, in age often 11 by 19 inches, and this year's growth 10 by 14 inches, obovate, bright dark green; spicules brown, but not prominent upon the joints; spines white, flattened, turning to a mottled, dirty gray, slightly twisted, with opalescent points, one-fourth to three-fourths inch long, 2 to 3 in number, but increasing to 12 or more at times upon old trunks; erect, spreading, with 1 or 2 lower ones recurved; fruit oblong-obovate, usually slightly tuberculate, with circular areoles one-eighth inch or less in diameter, bearing formidable brown glochids one-eighth inch long, dull red exteriorly; rind reddish yellow, turning to completely red at maturity; pulp blood-red, slightly mottled until dead ripe and clinging tightly to the seed, from which it is difficult to separate it.

The tuna mansa morada (*Opuntia* sp.) is one of the popular tunas of Mexico and one which has not been met with in the open country. For some reason it is not extensively grown, there being only a few plants in scattered orchards. It is finely flavored and of good size.

This sample was analyzed August 14, 1905, seven days after its collection. It was in good condition. The average weight of the

[a] Contrib. U. S. Nat. Herb., 3: 423, 1906.

fruit was 66.5 grams, which is somewhat below the average weight of the Mexican varieties but much heavier than those of the United States. It was one of the first analyzed after this work was undertaken. At that time the significance of the method of preparing the fresh fruit to be eaten was not fully appreciated. For this reason in this sample, as well as in Nos. 8037 and 8038, only the pulp, with that portion of the rind which would naturally remain after peeling the fruits as one would an apple, was analyzed. Nearly all of the best varieties discussed in this bulletin have had the pulp analyzed separately, and it is unfortunate that this fruit was not treated in a similar manner. However, it may be seen from an examination of the composition of the whole fruit, with epidermis and seed rejected, that it compares favorably with the best of those varieties that are reported in a similar manner in Table IV.

Since, as a rule, the pulp alone contains a greater percentage of nutrients than the whole fruit, it is likely that the pulp of this sample would have been about equal in value to that of the tuna cardona. The waste in this sample amounts to 21.83 per cent. If all the rind had been rejected, the waste would have been 46.75 per cent, about the same as in cardona. The total solids amount to 11.62 per cent, all but 1.22 per cent of which are soluble in water. The total solids of the juice calculated from its specific gravity amount to 9.38 per cent. The acidity of the juice is only 0.047 per cent, or less than the average of the pulp alone of all the fruits, which is 0.08 per cent. The average acidity for the whole fruits of all the Mexican varieties is 0.247 per cent. The sugars by reduction are somewhat less than one would expect from the soluble solids and high specific gravity. It is likely that the results for sugar, 7.82 per cent, are slightly low, although they would naturally be somewhat low because of the presence of the rind.

By peeling a quantity of these fruits and exposing them to the sun until air dry, the total dry matter was found to be 17.43 per cent. If the 4.65 per cent of seed be taken from this, there is 12.78 per cent of edible dry matter left, which, considering the small amount of water left in the air-dry sample, checks with the total solids (11.62 per cent) fairly well.

Collected at San Luis Potosi, Mexico, August 7, 1905, the sample consisting of 19 fruits from 4 plants.

TUNA TECA, TUNA BLANCA TECA, TUNA MEXICANA, TUNA AMERICANA.

(*No. 8050.*)

The tuna teca variety (*Opuntia* sp.) is known in the vicinity of San Luis Potosi by all of the appellations mentioned above, and it may be the same as forms which are discussed subsequently under other

names. The distinguishing characteristic of the fruit is that it is greenish white when mature. On the whole, it resembles very much the "mission pear" of the southwestern United States. It is very variable in spine characters, but this particular specimen had spines 2 to 5 in number on last year's joints, but increasing very much with age. The spicules are light reddish brown, seldom prominent upon the joints. The fruit is ovate-obovate, about 1¾ to 2¼ inches, yellowish green throughout; or, possibly, greenish white would apply better to the pulp. The seeds are apparently few and cling closely to the pulp.

This is a highly prized variety with fine flavor, good appearance, good size, and reasonably thin rind. It is one of the varieties that one will always find upon the market places in season.

An examination of the table will show the similarity in composition between this and the following numbers. In size No. 8050 is about a mean of that of the other two samples (Nos. 8146 and 8547). The waste amounts to 48.1 per cent, which is about the same as that of the other two. They are all characterized by high total and soluble solids but a slightly low sugar content. The total solids for the three amount to about 11 per cent, and the sugar from 8 to 9 per cent. It is easy to tell by tasting them that they are not as sweet as tuna amarilla, for example, but they have a very excellent flavor, which with their large size and thin rind makes them desirable fruits.

Collected at San Luis Potosi, Mexico, August 9, 1905.

TUNA BLANCA (WHITE).

(*Nos. 8146 and 8547.*)

The tuna blanca (*Opuntia* sp.) may be the same as No. 8050. The people of Zacatecas do not know the name tuna teca at all. This particular specimen is spiny like our "mission pear," but some plants are to be found which are almost destitute of spines or spicules; however, this character is not constant at all, even in the same plant. This tuna sells on the markets of Zacatecas for about the same price as camuesa; indeed, all of the large cultivated forms sell for about the same amount of money.

Both of these samples have been referred to in the discussion of tuna teca (No. 8050), which they very much resemble in both appearance and composition. This is one of the large cultivated fruits and has a good percentage of edible pulp, the seeds of which are often undeveloped and not so abundant as they are in many varieties. No. 8146 weighed 76.3 grams and No. 8547 weighed 123.75 grams. The total solids in the first amounted to 10.81 per cent and in the second to 12.35 per cent. Both fruits were slightly dextrorotary and con-

tained a fraction of 1 per cent of sucrose. There were 8.29 per cent of total sugars in the first and 8.99 per cent in the last sample.

No. 8146 was collected at Zacatecas, Mexico, September 21, 1905.

No. 8547 was collected at Zacatecas, Mexico, September 19, 1906.

TUNA RANCHERA (RANCH).

(*No. 8037.*)

A tall, open-branching tree 8 to 10 or 12 feet high, with black scaly trunk 8 inches, or often a foot, in diameter; joints ovate obovate, with often a tendency to be pointed at both ends, although the prevailing form is obovate, in proportion of 9 by 15 inches, which is a common size, rather light green; spicules yellow, infrequent upon the joints; spines short, one-half to five-eighths inch long, erect, spreading, 2 to 3 or 4 on young joints, but increasing to 10 on 3-year old ones, at this age turning to a dirty gray and apparently dropping off, divergent or a few recurved upon the edges of the joints; fruit large, 1¾ by 2½ inches, oval to obovate, with large circular areoles 1⅓ inches in diameter, bearing yellow, formidable spicules and hair-like fugacious spines, very dull, deep red, with some green exteriorly even when mature; rind greenish or mottled yellow and red; pulp, when rind is removed, presenting light orange yellow appearance, but mottled when cut open, the red color being situated mainly around the seed.

The tuna ranchera (*Opuntia* sp.) is a valuable cultivated variety which has a wide range in spine characters, some forms being nearly spineless. The fruit compares favorably in flavor with the other large mansa forms, such as amarilla, but the tunas are somewhat smaller. Although described as mottled, there is usually not enough coloring matter in either pulp or rind for slices of them to stain paper when they are laid upon it. The species should be classed with *Opuntia ficus-indica*.

Tuna ranchera is one of the few good fruits of which, unfortunately, we have no separate analysis of the pulp, both this and the rind having been included in one sample. The analysis given in Table IV will show this to be one of the best fruits so far as total solids and sugar content are concerned. It is about the same size (57.3 grams) as the cardona, and the composition of the edible portion when rind is included is also about equal to that of this fruit when it is prepared and analyzed in a similar manner. It was more dextrorotary than any sample included in our list, being +3.7 both before and after inversion. There was only 0.07 per cent of acid in this sample, which is quite low for any of the tunas where the rind is included with the pulp. A determination of the ash content of the different parts of the fruit shows 1.06 per cent of ash in the rind, 0.21 per cent in the pulp, and 0.74 per cent in the whole fruit.

The fact that there was 85.08 per cent of edible portion simply shows that the fruit was peeled by removing only a very small part of the rind.

Collected at San Luis Potosi, Mexico, August 7, 1905.

TUNA TAPONA[a] (CORK OR PLUG[b]).

(*No. 8065a.*)

When well developed, the tuna tapona (*Opuntia robusta* Wendl.; Cat. Herrenh., 1835) is one of the most attractive of the native Mexican tunas. It is almost globular, more or less tuberculate, and blood red when ripe. It thrives nicely at Riverside, Cal. Like many other species, the pulp becomes edible while the rind, which is red when mature, is still perfectly green. In the early part of the season the fruit upon the market is, therefore, largely green, while later it is blood red. Maturing as it does very early, a great deal of the fruit is destroyed by birds, which eat it as soon as the pulp begins to turn red.

Although large and attractive in appearance, this is not considered a very good species of tuna, mainly on account of the deleterious effects which the Mexicans believe it exerts on digestion. It is said that it has a tendency to produce constipation and that death sometimes results from its use. However, it is extensively eaten.

Collected at Ypina, Mexico, August 18, 1905.

(*No. 8065b.*)

Specimens No. 8065b (*Opuntia robusta* Wendl. (?)) and No. 8065a are closely related, but there are constant differences which prevent our placing them together. No. 8065b is a larger plant throughout, and this is the main difference, although there are other minor points of distinction which when once seen are easily recognized. This one has joints which are larger, more nearly circular, and not so thick and plump as the common tapona of the San Luis Potosi region. The fruits in this variety are also larger, but otherwise the same, and the same distinctions are true regarding the flowers. Both forms grow fairly well at Riverside, Cal., but the writers have never seen this variety growing native like the other. There are nearly spineless forms of both varieties.

Because of its very large size and the fact that it was one of the very few fruits grown in the United States which were analyzed that appeared to be of much value, it is to be regretted that a more complete analysis of it was not made. A complete analysis of No. 8065a was made, however, and probably the greatest difference between these two samples is in size. The waste is less in this one. The solids, determined from the specific gravity of the juice, are just about the same, but there is a great difference in the acidity. No. 8065a contained 0.21 per cent of acid, while this one had only 0.07 per cent.

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[a] For description of the plant, see Bulletin 60 of the Agricultural Experiment Station of New Mexico, 1896, p. 69.

[b] Referring to its action on the bowels.

This is doubtless accounted for, in part at least, by the fact that the California sample was more mature.

These fruits are the largest analyzed, being three times the size of those of the tuna tapona from the State of San Luis Potosi, Mexico.

Forwarded from the A. S. White Park, Riverside, Cal., in August, 1905.

TUNA CARDONA.

(*Nos. 8051 and 8099.*)

The tuna cardona (*Opuntia streptacantha* Lem.[a]) (see Pl. I) is without doubt the most highly prized of all the Mexican tunas. It is smaller than the cultivated varieties, but is very palatable, and the Mexicans say it may be eaten in quantity without any deleterious effects. The whole fruit is purplish red throughout, with a pulp of much deeper color than the remainder, and the epidermis showing considerable scaly wax covering when fully ripe. In shape it is oval to subglobose, about $1\frac{1}{2}$ to $1\frac{7}{8}$ inches in longest diameter. The fruit resembles very closely the tuna cochinera and the tuna artona. It is rather doubtful whether it is specifically distinct from the latter, but it is certainly distinct from the former.

Many of the cultivated species produce larger tunas and ones which are just as palatable, if not more so; but the cardona has several advantages over the others. It is abundant, cheap, a native species, very palatable, and with no deleterious qualities such as the tapona and some of the others are said to possess. Frequently it is planted, but not usually, in protected orchards, for it is sufficiently spiny to need no protection. Cuttings are commonly planted in the open country, in order to extend the native thickets. It is especially abundant upon the markets of San Luis Potosi, Aguascalientes, and Zacatecas, where one may often find piles containing 30 to 40 bushels brought in from the surrounding hills and deserts.

In view of the fact that this is the most abundant, widely distributed, and most universally used of all the Mexican species considerable time has been devoted to a study of the composition of both the pulp and rind, and an analysis of both of these parts will be found in Tables I and II, respectively, while in Table IV an analysis of the fruit without the seed and epidermis is also given. In order to determine the effect of storage on the composition, analyses of samples at three different periods of storage have also been made, both in 1905 and 1906. The first analysis given in the table is that of the fresh fruit immediately after its receipt in the laboratory; the second that of fruit selected from the same lot as the first after

[a] Cact. Gen. et Sp. Nov., 62, 1839. See Bulletin 60 of the Agricultural Experiment Station of New Mexico, 1906, p. 65.

standing ten days, while the third is the analysis of fruits that had been stored, as packed for shipment, for twenty days.

The tuna cardona is at least equal in nutritive value to any of the tunas, although considerably below the average in size and not quite as highly flavored as the amarilla, the naranjada, or the camuesa.

Sample No. 8051 was smaller and had more rind and seed than the other two samples. It had only 34.8 per cent of edible pulp, 11.47 per cent of solids, and 9.76 per cent of sugar as dextrose, this being less than was found in the other samples, doubtless due to the fact that eighteen days elapsed between the collecting of this and the second sample, thus giving the latter time to more fully mature.

No. 8099 was, as stated above, analyzed at three different periods for both the years 1905 and 1906, and the results are reported under Nos. 8099, 8099a, and 8099b in Table II. The rind was also analyzed and the results reported in Table I. No marked difference in the composition of the pulp or rind of the fruit when stored was noticed beyond what might be expected in different fruits of the same variety. One very noticeable change on standing, however, was the loss in weight of the rind and a corresponding decrease in the weight of the pulp. For the purpose of showing these changes the weights and percentages of the fruit and its rind and pulp for the different periods of storage during the seasons of 1905 and 1906 are given in Table VI.

TABLE VI.—*Effect of storage on weight and relative amounts of rind and pulp of the tuna cardona.*

Condition of fruit.	Weight in grams.		Rind.		Pulp.	
	1905.	1906.	1905.	1906.	1905.	1906.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Fresh	50	60.5	42.66	48.92	54.02	47.69
Stored for ten days	49	53.15	51.53	50.0	45.08	46.75
Stored for twenty days	47	....	61.70	....	35.35	....

The figures here given would seem to indicate that the water in the fruit passes from the pulp into the rind, but if such is the case this movement takes place without any material change in the composition of either pulp or rind that could be detected in the analysis.

The amount of acid in this fruit was unusually low both in the pulp and the rind. In the pulp of all the samples it averaged 0.05 per cent, and in the rind 0.21 per cent, which is less than half of the average for all the other Mexican samples.

The juice of every sample of No. 8099 tested was dextrorotary before and after inversion. Sometimes both polariscope and reduction methods showed a very small amount of sucrose in the pulp, and still more in the rind, which at times seemed to have as much as 1.5 per cent. The rind of none of the fruits contained as much total

sugar as did this one, 7.2 per cent, which is almost as much sugar as the pulp of average temperate-zone fruits. The total sugars as dextrose were determined in seven different samples of cardona, and the average for these determinations was 10.22 per cent.

No. 8051 was collected at Alonzo, Mexico, August 11, 1905.

No. 8099 was collected at Aguascalientes, Mexico, August 29, 1905.

No. 8436 was collected at Aguascalientes, Mexico, September 4, 1906.

TUNA PALAMITA.

(*No. 8038.*)

A tall, open-branching cultivated pear 10 or 12 feet high with a black scaly trunk 6 to 10 inches in diameter; joints obovate, in proportion of 6½ by 12 inches, which is a common size, slightly bluish green, becoming cracked and scaly with age; areoles obovate, about one-sixteenth by one-eighth inch, but increasing slightly with age; wool tawny; spicules light brown; spines flattened, triangular, twisted, some recurved, others erect divergent, one-half to 1 inch long, white with opalescent darker points, 2 to 4 in number, but increasing to 6 or 7 at age of 3 years, and increasing slightly even beyond this, but becoming abraded from old trunks; fruit about 1½ by 2¼ inches, ovate obovate, mottled, and dull red when fully matured, rind finally turning to a streaked brownish red and pulp mottled.

The tuna palamita (*Opuntia* sp.) is formidably protected with light-brown spicules one-sixteenth inch or more long from circular areoles about one-half inch apart. It is well flavored, but not promising, on account of the many spicules. The writers have never seen this species except in cultivation. The fruit is sweet and palatable, and were it not for its small size (33.1 grams) and large number of spicules it would be very desirable. No separate analysis was made of the pulp, unfortunately; but judging from the analysis of the whole fruit there are few tunas whose edible portion shows a superior composition. There is 12.43 per cent of total solids in the whole fruit and 8.87 per cent of sugar.

Collected at San Luis Potosi, Mexico, August 7, 1905.

TUNA AGUA-MIELILLA (HONEY WATER).

(*No. 8119.*)

A tall, open-branching native tree 12 to 25 feet high with a bare scaly black trunk 10 to 14 inches in diameter; joints ovate obovate, about 8 by 12 inches, which is a common size, deep dark green, soon turning to a gray black; spicules reddish brown, but never prominent upon the joints; spines white, becoming mottled, flattened, twisted, erect, divergent, 4 to 6, with lower and usually two laterals recurved; flowers (only two or three seen) deep orange, with red in midribs of outer segments, always causing them to look red when closed; style bright red, filaments lighter red, stigma yellow with streaks of red through outside of the 6 or 8 divisions; fruit small, subglobose to obovate, about 1½ inches in longest diameter, deep dark red with darker pulp, which is easily separable from seed, formidably protected with small circular areoles containing bunches of reddish brown glochids surrounded by the blackened ends of the wool.

As the popular name suggests, the agua-mielilla (*Opuntia* sp.) (Pl. IV, fig. 2) is a very sweet and palatable tuna, but it is too small to compare favorably with the cultivated forms and the better wild species, such as the cardona. These fruits averaged 30.84 grams in weight, which is less than half the average size of the Mexican species. Another serious objection is the large percentage of refuse in rejecting the thick rind, which amounts to 57.72 per cent. The solids and soluble solids (10.98 and 10.78 per cent, respectively) are high. The acid (0.024 per cent) is less than was found in any of the fruits. The percentage of proteids (0.89 per cent) is not high for fruits generally, but is more than was found in the other samples of prickly pears.

The total sugars amount to 8.84 per cent. No sucrose was found by reduction methods and only a very small trace by polarization, the readings being to the right before and after inversion. Because of the large quantity of rind an analysis was made to determine the nutritive value of this portion. The results are recorded in the table of analyses of the rinds (Table I), and from these it may be seen to have 7.27 per cent of solids in the juice, of which only 2.76 per cent is sugar.

Collected at Dublan, Mexico, September 12, 1905.

TUNA LEONERA.

(*No. 8102.*)

A tall, very open-branching tree 15 feet high, largely used for hedges and line plantings. Joints deep dark green, about the same color as the cardona, obovate, about 5 to 7 inches by 8 to 12 inches; spicules reddish brown, not formidable upon the joints, really seldom visible except in the spineless areoles at the base; spines 4 to 7 on last year's joints, but increasing very much on old wood, white, turning to a mottled condition and finally to dirty black, flattened, twisted, 1 to 2 inches or more long, and erect, with upper shorter, spreading, and lower usually recurved; flowers (only two seen) orange with greenish filaments, reddish style, and light green stigma; fruit almost globular, deep dull red, with pulp darker and rind of medium thickness, formidably protected with reddish brown spicules from small circular areoles about one-fourth inch apart; seed easily separable from pulp.

The tuna leonera (*Opuntia* sp.) is small, but has a very good flavor, and is consequently well thought of in parts of Mexico. It is eaten fresh and also employed in the manufacture of miel, melcocha, and queso, for which it is said to be admirably adapted. The composition of the edible portion, as seen from the analysis in Table II, shows it to be one of the three best fruits, but, as with agua-mielilla, its small size and thick rind prevent it from being classed as high as it would otherwise be. The fruits weighed only 30 grams, and 68.66 per cent of this was rind, which, with the 3.33 per cent of seed, left only 28.01 per cent of edible pulp. The solids of the edible portion

amounted to 13.21 per cent, 10.78 per cent being sugar. By reduction none of this was found to be sucrose, and polarization only showed 0.38 per cent. Both polarizations were to the right.

Collected at Encarnacion, Mexico, September 1, 1905.

TUNA PACHONA.

(*Nos. 8141 and 8546.*)

A tall, rather compactly branched tree 10 to 15 feet high, with a black, scaly trunk 6 to 10 inches in diameter; joints ovate-obovate, about 7 by 13 inches, deep dark green, with waxy white covering often prominent, resembling the cardona in color very much, but on the whole a little lighter; areoles 1 to 1¼ inches apart, ovate to circular; spicules bright reddish brown, but often yellowish at their bases, not often formidable on joints except at the bases of the younger ones; spines white, flattened or triangular, with translucent, bone-like tips, usually slightly twisted, somewhat but never tightly recurved, 2 to 5 in number; flowers not seen; fruit red, becoming decidedly purplish when fully matured, formidably protected with large bunches of reddish brown glochids from large circular areoles.

The tuna pachona (*Opuntia* sp.) is a bright, clear red fruit, which becomes deep red to purple when completely ripe. It is one of the most attractive of the leonero–opalilla–agua-mielillo group, and is largely used in the manufacture of queso and other pulp products. It sells on the day of collection upon the markets of Zacatecas at the rate of seven or eight for a cent, while amarillas, camuesas, etc., are selling at the rate of two for a cent.

The tuna pachona closely resembles the tuna cardona in composition. The average weight of the individual fruits of the cardona variety collected in 1905 was 49 grams, while the pachonas for the same year averaged 48.2 grams. The two resemble each other also in having a "mealy" juice—that is, when the juice is expressed there is a considerable amount of very finely divided solids in suspension.

The pachona sample collected in 1906 (No. 8546) was about the same in size as the one collected in 1905, and the amount of seed and rind, as well as the composition of the pulp, was about the same in both. The total solids amounted to about 12 per cent, and a calculation of the solids in the juices of the two from their specific gravity shows this to be not far from 12 per cent for both samples, while the reducing sugar amounted to about 9 per cent.

Strange to say, No. 8141 was dextrorotary to a fraction of a degree both before and after inversion and No. 8546 was slightly levorotary in both cases. The latter was more fully matured than the former.

No. 8141 was collected at Zacatecas, Mexico, September 19, 1905.

No. 8546 was collected at Zacatecas, Mexico, September 19, 1906.

TUNA CHAVEÑA.[a]

(*Nos. 8100 and 8136.*)

When fully ripened the tuna chaveña (*Opuntia* sp.) does not differ very much in outward appearance from the tuna cardona. It is, however, slightly longer and lighter in color, especially during the ripening period. It differs also in being protected by yellow instead of reddish brown spicules and in maturing about six weeks or two months later. The chaveña and its closely allied varieties are among the latest to mature in the autumn. With it its two varieties are almost always associated. The tuna caidilla differs from it in having rather smaller joints and in the one important characteristic of dropping its fruit as soon as mature. The Spanish name "caidilla" is probably derived from "caier," to fall. The fruit is said to remain in good condition upon the ground for a month or six weeks. The other variety is the tuna cascarona, differing also from the chaveña in having somewhat larger and more uniformly circular joints and possibly slightly larger tunas. These three forms are very closely related and would scarcely be considered distinct species by the most critical taxonomist, but they are quite well recognized by the Mexicans, who will pick them out, especially during the fruiting season, with considerable certainty. As previously stated, the tuna chaveña, together with its varieties, matures late in the season, and its fruits are best adapted for winter use. In the vicinity of Aguascalientes large quantities of these are stored and placed upon the market continuously through April. They are packed, as stated elsewhere in this bulletin, in well-aerated situations in alternate layers with straw or hay. Specimens which were examined as late as the middle of April were in a good state of preservation.

Although somewhat underripe, No. 8100 had evidently attained its full growth and sugar content. The tunas averaged 11.23 grams heavier than the fruits of No. 8136, which were gathered in the same locality two weeks later. This variety is about an average size, but it is characterized by a very large amount of rind in proportion to pulp. The percentage of seed is somewhat less than was found in some of the other varieties, but the proportion of rind is very large, and is not edible. When this was rejected the total refuse was about 75 per cent. Because of the large amount of waste, the rind of No. 8100 was analyzed and found to contain 4.97 per cent of sugar. The acids were rather high in the rind (0.96 per cent), which was probably due to the fruit not being thoroughly ripe. Both samples were somewhat similar in composition. The percentage of solids, sugars, and proteids of No. 8136 was somewhat greater than was found in the greener sample, by far the greatest difference being in the pro-

[a] See Bulletin 60 of the Agricultural Experiment Station of New Mexico, 1906, p. 73.

teids. The polarizations were to the right in both samples both before and after inversion. No sucrose was found by reduction in either, but the polarizations seem to show 0.24 per cent in No. 8136. This is about an average of the Mexican fruits so far as sugar and proteids are concerned. The test with iodin failed to show any starch in No. 8100.

Neither sample changed its color when evaporated to dryness on the water bath as do many of these fruits.

No. 8100 was collected at Aguascalientes, Mexico, August 29, 1905. This specimen was obtained from the very earliest tunas to mature and was really considerably underripe. The natives had not yet begun to use these fruits.

No. 8136 was collected at Aguascalientes, Mexico, September 15, 1905. This specimen was none too ripe, although the ripest fruits obtainable were selected for the analysis. The natives were just beginning to eat them at the time this sample was collected.

TUNA DURASNILLA BLANCA (WHITE PEACH).[a]

(*Nos. 8143 and 8545.*)

The tuna durasnilla blanca (*Opuntia leucotricha* DC.)[b] is a light yellow fruit when mature and reaches a size of 1¾ by 2¼ inches, but is usually smaller than this. It is one of the very few aromatic tunas of Mexico, although Mr. Francis Eschauzier states that this is a common characteristic of the tunas which have become naturalized in southern Spain. Differing from many species, the rind of this fruit assumes more of the consistency and flavor of the pulp when mature and is consequently eaten, the practice usually being to cut off the peel rather roughly, leaving about one-half of it attached to the pulp when the operation is completed. In this way about one-half of the peel is consumed with the pulp. To many foreign tastes this is a pleasant fruit on account of its slight pungency, the other species being often complained of as insipid. This, however, is no more true of the tunas than of many other subtropical fruits. See the discussion under No. 8150.

No. 8143 was collected at Gutierrez, Mexico, September 20, 1905.

No. 8545 was collected at Zacatecas, Mexico, September 19, 1906.

TUNA DURASNILLA COLORADA (RED PEACH).

(*No. 8150.*)

The writers are unable to discover any constant difference, except that of color, between No. 8150 (*Opuntia leucotricha* DC.)[c] and No.

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[a] See Bulletin 60 of the Agricultural Experiment Station of New Mexico, 1896, p. 75.

[b] Rev. de la Fam. de Cact., 119, 1829.

[c] Rev. de la Fam. de Cact., 119, 1829. See Bulletin 60 of the Agricultural Experiment Station of New Mexico, 1896, pl. 4.

8143. Both forms are aromatic and both are eaten with a portion of the peel attached to the pulp. Both have formidable spicules and hair-like fugacious spines of the same color. The rind and epidermis are most highly colored in this variety. The pulp becomes red very tardily, and then it is only mottled, the red being confined to that part of the pulp adjacent to the seed.

This fruit resembles No. 8143 as much in its chemical composition as in its botanical and physical characteristics, and for this reason the samples are discussed together. Since both rind and pulp of these two fruits are usually eaten, a complete analysis has been made in both fruits of each of these portions separately, as well as of the whole fruit (minus seed and peel), and the analyses as given in Tables I, II, and IV will show a remarkable similarity in the composition of the different parts of both. The average weight of each sample was 42.9 grams for No. 8143 and 40.6 grams for No. 8150, both being considerably below the average weight and size of the largest tunas.

Like the tuna chaveña (Nos. 8136 and 8100), these fruits have a very thick rind (about three-eighths of an inch), but inasmuch as it is palatable this can not be offered as much of an objection to them; yet while the rind of both fruits is superior to the rind of other fruits examined, with the exception of the tuna cardona (No. 8099), it is not equal in value to the pulp either in composition or flavor, and the same fruit with a thinner rind would, of course, be preferred. As mentioned before, it is doubtless the presence of a large amount of plant mucilage and salts of organic acids that renders the rinds unpalatable, and in No. 8150 these were found to be present in less than one-half of the quantity usually found in this portion of the fruit, as shown by the amount of alcohol precipitate (see Table I). The amount of ash was also considerably less in both samples than is usually found in the rind. About the only marked difference in the two fruits is in the amount of acid, there being more than twice as much acid in the white variety (No. 8143) as was found in the red sample (No. 8150).

While as before stated these fruits are quite similar in composition, there was found somewhat more pulp in the durasnilla blanca than in the durasnilla colorada, but the total and soluble solids, the proteids, specific gravity, and sugars are practically the same in both. As in the rind, the acid in the pulp of the former is more than twice that in the other. Both of these fruits are smaller and contain less sugar and other nutrients than some of the other samples, but the palatability of their rinds makes them desirable fruits.

Collected near Zacatecas, Mexico, September 22, 1905.

TUNA VINATERA.

(*No. 8134.*)

A tall, open-branching plant, often 12 to 15 feet high, with a gray scaly trunk 8 to 12 inches in diameter; joints prominently pubescent, tuberculate, narrowly obovate, 3 to 4 inches by 10 to 14 inches in last year's growth, light yellowish green; spicules lemon yellow, very formidable near base of joint but not so prominent above, often one-fourth inch long; spines white, erect, spreading, flattened, and twisted, with prominent translucent, bone-like tips, as much as 1¾ inches long, 2 to 4 or 5 in number, very formidable and stout, increasing rapidly with age and enlarging the areoles upon the old trunks to often one-half inch in diameter, and containing as high as 30 strong spines; flowers deep orange with red in midribs of outer segments, which are irregularly serrated and often cleft; filaments and style red, with pulp deeper colored than rind and clinging closely to seed, pubescent, tuberculate, deeply pitted at top, in this respect much like fruits of some of the species of Nopalea, formidably protected by yellow glochids from triangular areoles three-sixteenths to five-sixteenths inch apart.

Although very pleasantly flavored, the tuna vinatera (*Opuntia* sp.) has many disadvantageous characteristics. The fruit is small, the pulp clings closely to the seed, and the spicules are very numerous. It is quite extensively eaten in the field but seldom found upon the markets and is not very highly prized. It is the smallest of any of the fruits analyzed with the exception of one or two samples of little or no nutritive value. This variety averages only 24 grams per fruit, but the rind is not so thick as in some of the other fruits of good quality, like the leonera and the agua-mielilla. The edible pulp constituted 50.17 per cent of the fruit, and this had 12.14 per cent of solids, nearly all soluble, 10.22 per cent being sugar. No sucrose was found by reduction, and only a trace by polarization, the polarization being +2.3 before and +2.1 after inversion.

Collected at Aguascalientes, Mexico, September 16, 1905.

TUNA JOCONOXTLE.

(*No. 8135.*)

A medium-sized, rather compactly branched native plant 6 to 10 feet high, with a gray scaly trunk 6 to 8 inches in diameter; joints large, obovate, in proportion of 8 by 11 inches, which is a common size, minutely papillate hairy, soft and silky to the touch, dull green, becoming yellow and scurfy and finally gray scaly; areoles circular, about 1 inch apart; spicules yellow and rather prominent even on joints; spines white, turning to a dirty gray, flattened, slightly twisted, weak, erect divergent, very unequal in length, longest about 1 inch, the lower often somewhat recurved; flowers yellow; fruit subglobose to slightly obovate, about 1¾ inches in diameter, dull red with pulp deep red and rind lighter, papillate hairy, with circular to obovate areoles about one-fourth inch apart.

There are several very distinct varieties which pass under the common name of joconoxtle (pronounced *ho-con-ox-tle*) (*Opuntia* sp.). We are not certain that they all belong even to the same botanical species. The most obvious characteristics are found in fruit colora-

tion, but there are other taxonomic distinctions also. This variety has fruit red or reddish purple throughout. Another variety has green fruit with red pulp; another has fruit green throughout when fully mature. All of the varieties agree, however, in one respect, namely, they are not palatable in the fresh state. They need to be cooked before being eaten.

The rind in this species is comparatively thick and the pulp not palatable. It is therefore not eaten until cooked. Its main value is in the manufacture of preserves, for which there is a large use.

A rather complete analysis has been made of both rind and pulp, and the composition of these parts, as well as that of the whole fruit, is reported in the different tables. The average weight of this variety is 41.17 grams, which is below the average weight of tunas generally. Of this, 68.46 per cent is rind, only 26.95 per cent being pulp free from seed. The tuna joconoxtle contains less nutrients than any of the edible samples received from Mexico, with the possible exception of the tuna cuija.

A comparison of the analysis of the whole fruit of these two samples in Table IV shows the total and soluble solids in the joconoxtle to be 7.02 and 5.34 per cent, respectively, while for the tuna cuija they are 8.45 and 7.50 per cent, respectively. But the cuija has only 4.18 per cent of sugar, while the joconoxtle has 4.76 per cent in the whole fruit. The pulp of the latter has 7.74 per cent of sugar, but there are no data for sugar in the pulp of the former.

These are the only tunas from Mexico with less than 10 per cent of total solids and with so low a percentage of sugar. In this respect they more nearly resemble those forms native to the United States.

Collected at Aguascalientes, Mexico, September 15, 1905.

PRICKLY PEAR, NOPAL.[a]

(Nos. 1 to 6, William Sinclair, collector.)

Very little use is made of the fruit of *Opuntia lindheimeri* Engelm.,[b] and our analyses show that it has comparatively little merit as a food. Occasionally a family is found which makes a sort of preserves of the peeled fruits; others dry them, while still others eat them in the fresh state. Usually the fruit simply drops off of the plants and is eaten by hogs and cattle. There is a strong opinion prevalent among both Americans and Mexicans in portions of southern Texas that the fruit produces injurious effects. However this may be, it is certain that it is very often eaten, although not very palatable, with no injurious consequences.

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[a] Names of the plant. These names apply to all species of the flat-jointed Opuntias.

[b] Boston Jour. Nat. Hist., 6: 207, 1850. See Bulletin 60 of the Agricultural Experiment Station of New Mexico, 1906, p. 32, and Bulletin 91 of the Bureau of Animal Industry, U. S. Dept. of Agriculture, pp. 9–11.

Six samples of this species have been analyzed, all collected by Mr. William Sinclair at San Antonio, Tex., as follows:

(1) Collected August 1, 1905. This is the only one of those fruits from San Antonio, Tex., which had the pulp and rind analyzed together as one sample, and for that reason it is not readily comparable with the other five samples in its solids and its sugar content, but it is probably one of the best fruits from that locality.

The tables show about twice as much sugar in sample No. 2, which was collected six or seven weeks later in the season, but the solid matter is about the same for both, and the difference in sugar can be largely accounted for by the fact that the rind is included in sample No. 1.

The tables show a high percentage of edible portion because only the seed and a very thin epidermis are included in the waste. The fruits were crimson in color, averaged 43.5 grams in weight, and were about 1½ by 2½ inches in size. The sample had 3.94 per cent of total reducing sugars and 0.88 per cent of sucrose. The determination of total solids was lost, but the solids in the juice calculated from the specific gravity were 7.74 per cent.

(2) Collected September 19, 1905. This sample of *Opuntia lindheimeri* was collected about seven weeks later than the previous one and was the largest and best sample from San Antonio. The fruits were 1¾ to 3 inches in diameter and weighed on an average 71.63 grams. The rind of this sample was very thick (about one-fourth inch in its thinnest part) and was a very deep purple. As in all the samples from Texas, there was a large percentage of waste. There were 7.78 per cent of total solids and 7.18 per cent of total sugars.

(3) Collected November 17, 1906. The individuals in this sample averaged about 1 by 1½ inches in size and weighed 25 grams. Like all the fruits of this species, they were sour and unpleasant to the taste. In some of the fruits the pulp was gray or yellowish green in color. The rind was very thick and constituted 67 per cent of the total. Only the pulp was included in the analysis, and this amounted to 25 per cent of the fruit. It had only 5.68 per cent of solids. Of these solids, 1.18 per cent was acid, 0.48 per cent proteids, and 0.85 per cent total sugars. If this fruit were palatable the small amount of edible portion and the low percentage of solids and sugar would render it of little value.

(4) Collected July 4, 1906. The pulp only was included in the analysis of this sample. It amounted to 33.29 per cent of the whole fruit. There was 7.8 per cent of solids, of which 7.27 per cent was soluble, 5.24 per cent was sugar, and 0.88 per cent was acids calculated to H_2SO_4. It is interesting to note that while this fruit contained only 5.24 per cent of sugar it was the best sample of this

species. It was levorotary before and after inversion, both polarization and reduction showing a fraction of 1 per cent of sucrose.

(5) Collected October 16, 1906. This sample consisted of small somewhat shriveled green fruits, a number of which had begun to decay. They averaged 21 grams in weight. The rind was green to the pulp, but this was of a bright scarlet color.[a] Like the other samples, the proportion of rind and seed was very large, and only 32 per cent was edible. Of this, 7.13 per cent was solids and only 1.41 per cent was sugar. The writers were unable to notice any effect upon polarized light by the juice.

(6) Collected November 6, 1906. These fruits weighed on an average 26.54 grams. The pulp had only 5.33 per cent of solid matter, and this was quite unpalatable, as may readily be understood by referring to its analysis as given in Table II. Of this solid matter, 2.15 per cent was acid, and the fruits contained no sugar whatever.

SAMPLE NO. 2, NEW MEXICO COLLEGE GARDEN.

Both rind and pulp of Sample No. 2 (*Opuntia engelmannii cycloides*[b]) were of a deep red color; they averaged about 1½ by 2 inches in size, weighed 18.1 grams, and had about 200 seeds three-sixteenths inch in diameter.

In the analysis of this sample the rind was included with the pulp. The refuse, consisting of seed and peel, amounted to 28.53 per cent. The solids, calculated from the specific gravity of the juice, constituted 11.23 per cent. Of this, 1 per cent was malic acid, and 6 per cent was reducing sugars. By reduction 1.97 per cent of sucrose was obtained. By polarization it was 1.65 per cent.

In the vicinity of Hillsboro, N. Mex., the fruit of this species is prepared as an attractive palatable sirup. The juice is expressed in a fruit press, and is then boiled to one-fourth its original volume after the addition of one-sixth its weight of cane sugar. Boiling does not destroy the color in the least. The finished product is not only palatable, but is attractive in appearance.

Collected at Agricultural College, N. Mex., August 10, 1905.

TUNA CUIJA.

(*No. 8036.*)

The tuna cuija, pronounced *quee-cha* (*Opuntia engelmannii cuija* G. & H.[c]), is a deep purple fruit which ranges from subglobose to pyriform, about 1¼ by 2¼ inches in size, and is one of the most variable

[a] A common characteristic of late fruit of this species.

[b] Engelmann and Bigelow. Pacif. Ry. Rep., 4:37, pl. 8, fig. 1, 1856. See Bul. 60 of the Agricultural Experiment Station of New Mexico, 1896, p. 40.

[c] N. Mex. Expt. Sta. Bul. 60, pl. 2, 1906. For description, see Bul. 60, Agr. Exp. Sta. of New Mexico, 1906, p. 44, pl. 2.

species. Some forms are worthy of cultivation, being quite palatable and having a good proportion of pulp, while others are not fit to eat. When overripe, the color is very deep, almost black—so much so that the vendors upon the market places where they are sparingly sold often call them "tuna negra." The fruit is quite comparable with that of *Opuntia lindheimeri*. The areoles are very similarly distributed and the spicules somewhat more abundant.

No separate analysis was made of the pulp of this variety, but the analysis of the edible portion of the whole fruit shows this to be of little value compared to most of the other Mexican varieties. It resembles the joconoxtle in its composition, but the fruits are only about one-half as large, the average weight of the cuija being only 21.05 grams. The refuse is reported in Table IV as only 15.38 per cent of the fruits, but this is because the rind was all included in the edible portion, except the thin epidermis. The total solids of the fruits were 8.45 per cent, but only 4.18 per cent was sugar.

Collected at San Luis Potosi, Mexico, August 6, 1905.

SAMPLE NO. 3, NEW MEXICO COLLEGE GARDEN.

The average weight of the fruits of Sample No. 3 (*O. lævis?* Coulter[a]) was 29.5 grams. They are of a dark purple color, and the juice is a brilliant red both for the rind and pulp. The pulp was separated from the rind and seed in a press. The edible portion obtained by this process amounted to 78.18 per cent of the fruit. The total solids were 10.11 per cent and the sugars 7.51 per cent. This was one of the few prickly pear fruits that were levorotary both before and after inversion. By polarization no sucrose was found, and only 0.14 per cent was found by reduction; it contained 0.22 per cent of acid calculated as H_2SO_4.

This is probably the most palatable prickly pear that is at present found growing in New Mexico, and while it is not eaten as a fresh fruit very extensively, it is used considerably by the Mexicans in the preparation of preserves.

Some of the pulp of this fruit was evaporated to about one-eighth of its original volume to a thin paste, without suffering any change in its color. This paste was used for coloring apple jelly and candy, and was found to serve admirably for the former purpose. Because of the danger or prejudice against the use of coal-tar dyes it may have some value commercially as a vegetable coloring matter. Candy colored by means of it lacked the brilliancy of that colored with coal-tar dyes, and it is doubtful whether it could ever be very generally used for this purpose. The paste prepared in this manner

[a] Contrib. U. S. Nat. Herb., 3: 419, 1896. See Bul. 60, Agr. Expt. Sta. of N. Mex., 1906, p. 43.

had 51.6 per cent of sugar, only 0.48 per cent being sucrose. By removing the sugar and insoluble solids from the material the coloring matter could probably have been concentrated to as rich a color as cochineal paste. The coloring matter of this fruit will be more fully investigated during the coming season.

Whether or not the fruits will ever prove of commercial value for the preparation of a coloring matter will, it is believed, depend solely upon the yield to the acre that can be obtained. This can only be determined by experiment.

Collected from the cactus garden of the New Mexico Agricultural College, August 20, 1906.

SAMPLE NO. 8022.

Sample No. 8022 (*Opuntia phaeacantha* Engelm.[a]) is rather small and too acid to be of use as an article of human food. It is pyriform, about 1 by 1½ inches, rather sparingly beset with small areoles having formidable yellow glochids one-eighth inch or less long. It is light reddish purple without and has a rind of the same color, but the pulp, which is quite acid, is greenish yellow and the seeds are comparatively large.

It will be seen that this brief description varies somewhat from that given in Bulletin 60 of the Agricultural Experiment Station of New Mexico. The writers can not tell about the character of fruit of the type of *Opuntia camanchica* for reasons stated in that publication, and the description is not explicit. It may be necessary later to admit under this specific name forms with fruits bearing the following colors:

(1) Reddish purple throughout.

(2) Reddish purple on outside and greenish yellow within.

(3) Reddish purple epidermis and rind and greenish yellow pulp.

The fruit was prepared for analysis by peeling the skin or epidermis with as little waste of the rind as possible, which was analyzed, together with the pulp, freed from seed. There was in this sample 15.84 per cent of seed, this being more than was found in any of the samples analyzed. The peel was only 12.06 per cent, making a total waste of seed and peel of 27.9 per cent.

The total and soluble solids were not determined in this sample, but the solids in the juice calculated from its specific gravity were 11 per cent, and the sugars amounted to only 3.35 per cent, making a purity coefficient of the juice of only 30.5 per cent, while with the juices of the best fruits it was as high as 80 to 90 per cent. This low coefficient in the purity of the juice is found in all the fruits with a

[a] Mem Am. Acad. (Plant. Fend.), 4:52, 1849. See Bulletin 60 of the Agricultural Experiment Station of New Mexico, 1906, p. 50, for notes on this and *Opuntia camanchica*.

low sugar content when the rind was included with the pulp in the analysis. The other solids doubtless consist of acids, salts of organic acids, and mucilage—1.58 per cent is acid calculated as H_2SO_4.

Reduction methods showed 2.6 per cent of the sugar to be sucrose, but we are inclined to believe that there must be an error in these results, since the juice seemed to have very little, if any, effect on polarized light and no sucrose was found by polarization.

Collected at El Paso, Tex., July 30, 1905.

SAMPLES NOS. 1 AND 4, NEW MEXICO COLLEGE GARDEN.

At the time of collection it was noticed that there were two kinds of mature fruits on the different plants in a plantation of this species (*Opuntia macrocentra* [a]) upon the college campus. They resembled each other in their outward appearance, except that sample No. 1, collected in 1905, was about twice the size of sample No. 4, collected in 1906. The pulp of No. 1 was red, while that of No. 4 was green or yellowish green. The fruits of sample No. 1 averaged 29.28 grams, while those of No. 4 weighed only 14.5 grams each.

Sample No. 1 was prepared for analysis by peeling off the epidermis and forcing the pulp and rind through muslin. The amount of edible portion obtained in this manner amounted to 78.46 per cent. The edible portion in No. 4 was obtained by subjecting the fruits to pressure and weighing the juice thus obtained. In this way only 59.68 per cent was edible. The total solids in No. 1 was not determined, but a calculation from the specific gravity of the juice shows the solids in this sample to be 8.92 per cent. The total solids in No. 4 was 12.08 per cent and the soluble solids 11.63 per cent. Calculated from the specific gravity of the juice the solids present in No. 4 amounted to 12.60 per cent. No. 1 had 0.85 per cent of acid, and No. 4 had 0.47 per cent, or about half the amount found in No. 1.

Both samples were levorotary at both readings and seemed to have some sucrose, the larger quantity being in No. 4.

No. 1 had 3.87 per cent of total sugars as dextrose and No. 4 had 9.03 per cent. The small fruit with the green pulp which was collected in 1906 was a better fruit than the one collected in the previous year, as may be seen from its composition. It has more solids and sugar and less acid. Whether this is due to the season, the fact that it was collected ten days later in the month, the difference in the size of the two samples, or varietal difference, the writers can not say. A difference in the color of the pulp is common in the prickly pears. Similar differences to the one noted here are common in *Opuntia engelmannii*, *O. lindheimeri*, *O. phaeacantha*, and many others.

[a] Engelmann, George. Synopsis of the Cactaceae of the Territory of the United States and Adjacent Regions. Proc. Am. Acad. Arts & Sci., 3:292, 1857.

TUNA JUELL.

(*No. 8035.*)

Tuna juell (*Opuntia imbricata* (Haw.) DC.[a]), pronounced *whay*, is the common cylindropuntia of the highland region of Mexico. The fruit is not eaten by either man or beast, so far as the writers have been able to determine. As the analyses show, it is very high in acid, and because of this and the presence of so much plant mucilage and the absence of sugar it is not at all palatable.

Before the advent of coal-tar dyes this fruit had an important place in the arts. The tunas were gathered, chopped up into small pieces, and boiled, the fiber and seed being filtered out and the extract used to dissolve and set cochineal dye. It is still used in this way to a limited extent. Experiments which the writers have conducted show it to be somewhat efficient for the purpose, especially in the coloring of woolen cloth. Its mordanting property is doubtless due to the large amount of acids and salts of organic acids present.

This is the only analysis of cane cactus (Cylindropuntia) included in this bulletin. The fruit of this group of cacti is not edible, nor was this particular sample. The analysis was made to determine its composition compared to the prickly pears. The fruits averaged 51.66 grams in weight. The percentage of seed was 9.68, which is higher than was found in any of the fruits except *Opuntia phaeacantha* (No. 8022).

The total solids were only 7.57 per cent, 5.54 per cent being soluble in water. The juice contained an unusually large quantity of plant mucilage, which rendered it so slimy that the writers could not determine the specific gravity at all by means of a Westphal balance, and upon attempting this determination with a gravity balance the unavoidable bubbles in the slimy juice caused the specific gravity to be only 0.903, or less than that of water, which is, of course, too low. The proteids present were about an average of what is usually found in the other tunas. The fruit contained 3.48 per cent of acid, which was found to be malic acid. This large percentage suggests a possibility of the use of the plant in the preparation of malic acid. No trace of sugar was found either by reduction or polarimetric methods.

An analysis of the ash of the soluble solids in this fruit is given below. A comparison of its composition with the composition of the ashes of the stems of the cacti as given in Table 2 in Bulletin No. 60 of the Agricultural Experiment Station of New Mexico shows it to be comparatively low in lime and high in alkali salts and sulphates.

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[a] Prodromus, 3: 47, 1828; *Cereus imbricatus* Haw., Rev. Pl. Suc., 70, 1821. See Bulletin 60 of the Agricultural Experiment Station of New Mexico, 1906, p. 97, pl. 7, fig. 2.

Composition of the ash in the soluble solids of the tuna juell.

	Per cent.
Silica, iron, and alumina (SiO_2, Fe_2O_3, Al_2O_3)	0.64
Chlorin (Cl)	4.09
Sulphuric acid radicle (SO_4)	5.12
Calcium (Ca)	7.15
Magnesium (Mg)	6.83
Sodium (Na)	Trace.
Potassium (K)	33.81

Collected at San Luis Potosi, Mexico, August 9, 1905.

MEXICAN STRAWBERRY.

(*No. 5, New Mexico College Garden.*)

The Mexican strawberry (*Echinocereus stramineus*[a]) is the only fruit included in this study outside of the genus Opuntia. The genus Echinocereus includes many species with edible fruits. In fact, the fruits of this genus are often preferred to the prickly pears, but their scarcity prevents their extensive use as a food. The fruits in the sample were collected somewhat late in the season and were probably not as good as some that matured earlier. They will not stand storage as well as prickly pears, for they ferment very quickly after being collected. These fruits are of a salmon color, weigh about 18 grams, and average 2 inches long and 1 inch in diameter at the largest part. They are formidably covered with long white spines, but these are completely and easily brushed off when the fruit is ripe. The fruit is covered with a greenish rind, which constitutes 30.38 per cent of the whole, but this represents the total refuse, since the small black seeds, which are almost as small as those of the strawberry, are eaten, and for this reason were included with the edible portion. The edible portion, therefore, amounted to 69.17 per cent, which is more than that of any of the prickly pears with their rinds rejected. The percentage of total solids of the edible portion amounted to 18.14, which is also higher than that of the prickly pear and can be explained, in part at least, by the presence of the seeds. The fruit differs from the prickly pears in containing nearly 3 per cent of sucrose. Its polarization readings were +1.3 before and −2.5 after inversion at 28° C. The total sugars were 9.3 per cent. The unusual amount of sucrose for a cactus fruit made them much sweeter than the prickly pears.

The juice had a very pleasing odor and taste, and if the plants were as abundant as the prickly pear they would be preferable as a food, as they are more palatable and do not, like the tuna, contain so many seeds that can not be masticated or readily removed from the pulp. Neither do they have so much plant mucilage as the tunas.

Collected August 17, 1906, from garden on campus of New Mexico Agricultural College.

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[a] Engelmann, George. Synopsis of the Cactaceæ of the Territory of the United States and Adjacent Regions. Proc. Am. Acad. Arts & Sci., 3: 282, 1857; U. S. & Mex. Bound. Sur., 2: 35, 1859.

PLATES.

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DESCRIPTION OF PLATES.

PLATE I. *Frontispiece.* Tuna cardona. A native and the most important of the prickly pears of the northern highlands of Mexico. Reduced to one-third natural size.

PLATE II. Harvesting the tuna cardona. Fig. 1. Gathering tunas for immediate consumption. Fig. 2. Peeling tunas for immediate consumption.

PLATE III. Drying tunas (tunas pasadas). Fig. 1. Peeling tunas for drying, Montesa, Mexico. Fig. 2. Drying tunas in the sun, Montesa, Mexico.

PLATE IV. A tuna seeder and several large prickly pears. Fig. 1. A seeder dissected. Fig. 2. Nopal agua-mielillo, Dublan, Mexico.

PLATE V. Prickly pear thickets. Fig. 1. A temporary camp in a pear thicket at harvest time, State of Zacatecas, Mexico. Fig. 2. First crop of tunas the second year from cuttings having two or three joints (nopal manso morado), San Luis Potosi, Mexico, August 20, 1906.

PLATE VI. Seeds of edible tunas. Natural size. Fig. 1. No. 8142, tuna naranjada. Fig. 2. No. 8036, tuna cuija. Fig. 3. No. 8037, tuna ranchera. Fig. 4. No. 8038, tuna palamita. Fig. 5. No. 8039, tuna mansa morada. Fig. 6. No. 8135, tuna joconoxtle. Fig. 7. No. 8134, tuna vinatera. Fig. 8. No. 8136, tuna chaveña. Fig. 9. No. 8141, tuna pachona. Fig. 10. No. 8050, tuna teca, tuna blanca teca. Fig. 11. No. 8051, tuna cardona (*Opuntia streptacantha*). Fig. 12. No. 8150, tuna durasnilla colorada. Fig. 13. No. 8143, tuna durasnilla blanca. Fig. 14. No. 8146, tuna blanca. Fig. 15. Tuna camuesa (*Opuntia larreyi* Web., type from Engelmann herbarium). Fig. 16. No. 8140, tuna camüesa (*Opuntia larreyi*(?)). Fig. 17. No. 8065b, tuna tapona (*Opuntia robusta* Wendl.(?)). Fig. 18. No. 8065a, tuna tapona (*Opuntia robusta* Wendl.).

FIG. 1.—GATHERING TUNAS FOR IMMEDIATE CONSUMPTION.

FIG. 2.—PEELING TUNAS FOR IMMEDIATE CONSUMPTION.

HARVESTING THE TUNA CARDONA.

FIG. 1.—PEELING TUNAS FOR DRYING, MONTESA, MEXICO.

FIG. 2.—DRYING TUNAS IN THE SUN, MONTESA, MEXICO.

DRYING TUNAS (TUNAS PASADAS).

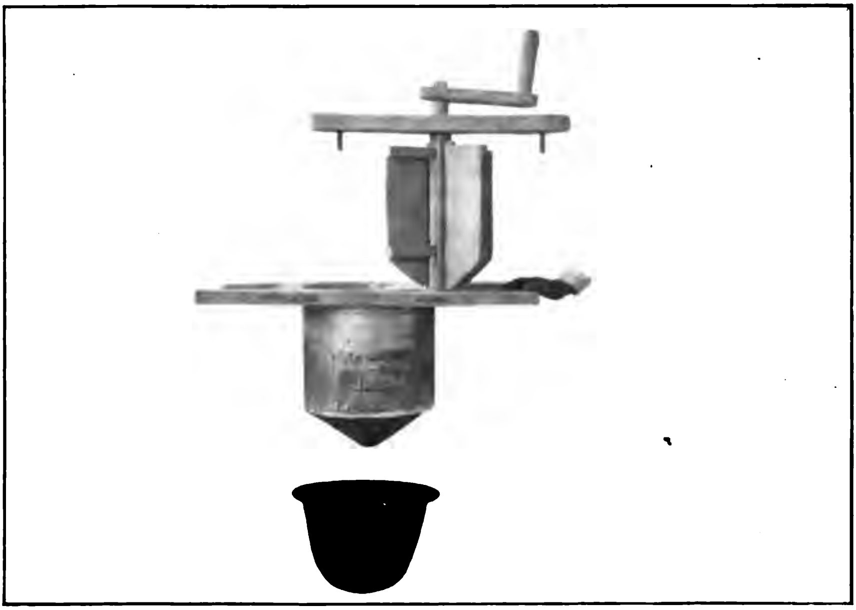


FIG. 1.—A SEEDER DISSECTED.

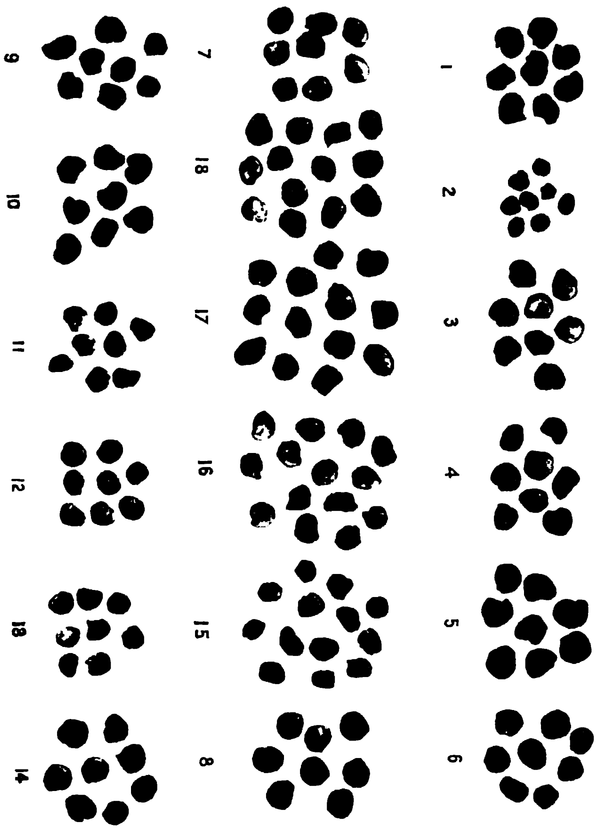
FIG. 2.—NOPAL AGUA-MIELILLO, DUBLAN, MEXICO.

A TUNA SEEDER AND SEVERAL LARGE PRICKLY PEARS.

FIG. 1.—A TEMPORARY CAMP IN A PEAR THICKET AT HARVEST TIME, STATE OF ZACATECAS, MEXICO.

FIG. 2.—FIRST CROP OF TUNAS THE SECOND YEAR FROM CUTTINGS HAVING TWO OR THREE JOINTS (NOPAL MANSO MORADO), SAN LUIS POTOSI, MEXICO, AUGUST 20, 1906.

PRICKLY PEAR THICKETS.



SEEDS OF EDIBLE TUNAS.

(Natural size.)

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY- BULLETIN NO. 117.

B. T. GALLOWAY, *Chief of Bureau.*

THE RESEEDING OF DEPLETED RANGE AND NATIVE PASTURES.

BY

DAVID GRIFFITHS,

Assistant Agriculturist, Farm Management Investigations.

Issued December 13, 1907.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1907.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 117.

B. T. GALLOWAY, *Chief of Bureau.*

THE RESEEDING OF DEPLETED RANGE AND NATIVE PASTURES.

BY

DAVID GRIFFITHS,

ASSISTANT AGRICULTURIST, FARM MANAGEMENT INVESTIGATIONS.

ISSUED DECEMBER 13, 1907.

WASHINGTON:

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 20, 1907.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 117 of the series of this Bureau, the accompanying manuscript entitled "The Reseeding of Depleted Range and Native Pastures," by Dr. David Griffiths, Assistant Agriculturist, Farm Management Investigations.

This paper embodies the results of successful experiments in the reseeding of native pastures and points out the character of the regions wherein success may be expected from the use of seed followed by little or no cultivation.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE RESEEDING OF DEPLETED RANGE AND NATIVE PASTURES

INTRODUCTION.

The most frequent inquiries referring to range management and improvement relate to the reseeding of native pastures which have been reduced in productiveness by neglect and mismanagement. The following pages, based upon observations and investigations covering a period of ten years, give only a brief summary of information. The subject is important to the entire country, for native or seminative pastures are common even in thickly settled communities of the East; but the discussion herein relates primarily to what was once the great free-grass country west of the Missouri River, which even in its most thickly settled areas still produces much forage upon virgin soil.

POPULAR CONCEPTIONS OF RESEEDING RANGES.

The very subject of reseeding presupposes a lack of cultivation or other artificial means of increasing feed production. It is often difficult to draw a distinction between native and tame pastures, for when any improvement is made in an artificial way through tillage or reseeding the pasture becomes a tame pasture in proportion to the tillage and seed used. For the purposes of this discussion a liberal interpretation is adopted to permit a discussion of any grade of pasture up to a thoroughly tilled one of tame grasses.

The opinion is prevalent in range sections that any improvement in native pastures ought to be and must be made by simply sowing seed and giving it no attention other than to pasture the crop that it produces. In other words, that a grass, a shrub, or some other forage plant should be found which when scattered among native vegetation will supplant that vegetation, at least in part. It is expected that plants may be introduced which will be better adapted to the prevailing conditions than those which have found lodgment there and managed to develop, continually becoming better adapted to the surrounding environment through past centuries. While such an accomplishment is not at all impossible, the chances are

many to one against success in such a venture. Plants introduced through seeding and allowed to shift for themselves seldom succeed, and success is attained in such cases only when they have particular characteristics and are placed under peculiarly suitable conditions.

RESULTS ACCOMPLISHED.

The State agricultural experiment stations located in the stock-range sections, some independently and some in cooperation with the Department of Agriculture, have given much thought and attention to the feature of range improvement by reseeding in all its phases. The Department alone in a single year gathered and distributed nearly four tons of seed of native grasses, which was mostly used in experiments in the improvement of native pasture lands. A large quantity of seed of cultivated varieties of forage plants has been employed also, and various grades of cultivation, ranging from simply scattering seed to nearly thorough cultivation, have been resorted to. These lines of work have extended over a period of ten years or more with profitable results.

NATIVE SPECIES.

There is logic in the supposition that species growing under given conditions are better adapted to those conditions than introduced species and that they will thrive better when encouraged by scattering and by partially covering their seeds than introduced kinds until conditions are more or less changed. These changes may be brought about by the destruction of the native vegetation, by overgrazing, by thorough cultivation, or by any other means which interferes with the natural order of the development of the plants. In other words, when forage plants are introduced it is usually necessary to give them special care in order that they may be able to compete with native species. This applies to practically all cultivated crops. There are certain notable exceptions to this general rule in certain special natural conditions, and it is these exceptions that are of especial interest.

Acting upon the suggestion that the native species are best adapted to the natural conditions in which they are found, much time was spent by the State agricultural experiment stations and by the Department of Agriculture a few years ago in experimenting with the reseeding of native pastures with native species. Large quantities of native seed were gathered and planted under various conditions.

There are many difficulties in the way of improving native pastures by the use of seed of native species, the chief obstacle being the difficulty of securing the required seed. Many, possibly the

majority, of our best native species of forage plants have such poor seed habits that it is difficult to reduce the expense of gathering them to an economic basis. There is usually no trouble in getting small quantities of seed and in growing the plants in conventional grass-garden plots upon an experimental basis and under thorough cultivation, but this is a very different thing from the reseeding of native pastures, with little or no cultivation.

Another obstacle is the difficulty of judging the seasons properly. Seed is more likely to be collected during a favorable season when the crop is good, and it is then sown in the following year. The next season after a favorable one is more than likely not to be favorable for seed germination. The fact is commonly lost sight of that, although one is placing the seed of native species under conditions more or less similar to those found in nature, when one gathers and sows seed upon uncultivated soil the chances are against its success. The likelihood of seed of perennial species of grasses growing under natural conditions is very small as a usual thing; and it is the perennials that are most valuable. To maintain a perennial species it is necessary for its seed to grow but seldom. Then when it is considered that many species propagate vegetatively we recognize how uncertain the chances are for reproduction from seed sown unless the soil receives some artificial treatment in the shape of cultivation for the subjugation of competing native plants. Our best cultivated pasture grasses to-day are Kentucky bluegrass for the North and Bermuda grass for the South. But the propagation of these grasses from seed is far from satisfactory, for under the most favorable range conditions it would take at least three or four years to thoroughly establish bluegrass. It is difficult in the first place to procure the seed of native species; in the second place, the seed obtained is often of poor germinating quality, because many of the plants habitually get along without the use of seed, which they produce imperfectly; and, in the third place, it is difficult to sow the seed at the proper season, for in the arid West it is only in favorable seasons that conditions are suitable for seed germination. It may therefore happen that seed failing to germinate would have been successful if sown in a more favorable season. It will be readily perceived, therefore, why the list of native forage plants which have been successfully used, even on a small scale, in the renovation of native pastures is small, although there are many species, no doubt, that can be domesticated when serious attention is devoted to the subject.

Upon the eastern slope of the Black Hills of South Dakota some farmers have improved their meadows by sowing seed of western wheat-grass (*Agropyron occidentale*) which they collected from their hay crops. Here, however, in the main, good results are secured by

irrigation. Water is commonly applied to raw prairie land, which in a short time, if the drainage is proper, will produce good crops of this grass to the exclusion of almost everything else. The grama grasses, especially, under this treatment disappear very rapidly before this species, which propagates by creeping rootstocks. Too much water or improper drainage, on the other hand, causes this western wheat-grass to be replaced in turn by rushes (*Juncus* spp.) and sedges (*Carex* spp.), as is the case in many areas of Montana and Wyoming. This is especially noticeable in certain cities of South Dakota where artesian water is employed in excess upon lawns of native grasses.

Something may be done with western wheat-grass in a small way to improve native pastures in some of the western prairie States if the seed is covered by harrowing and careful attention is paid to seeding in favorable seasons only. It is next to useless to sow without any cultivation, and with cultivation the expense would be prohibitive except on a small scale where labor can be used for the work in slack times when not needed for other purposes, and even then it is quite probable that greater returns would be secured by placing the ground in a thorough state of cultivation and seeding to some well-tried tame grass.

Bunch-grass (*Agropyron spicatum*) has been used successfully on a small scale upon denuded pastures in eastern Washington, but at almost prohibitive expense. Lands in this section once well stocked with this species recuperate slowly under protection from overgrazing, even without artificial seeding.

A closely related species (*Elymus triticoides*) generally inhabits the low, moist, nonalkaline bottoms in the Great Basin country, but also extends into the interior valleys of California. Several unsuccessful attempts have been made to use this species, but the writer considers all of the experiments known to him ill advised. This grass is adapted to low bottoms which receive at least one flooding each year. Its seed habits are first class, and it resembles western wheat-grass in both habit and general appearance. In many localities in northeastern Nevada and southeastern Oregon this grass has spread to sagebrush land and produced good crops under the influence of partial irrigation in the shape of a single diversion of spring flood waters on the lower sagebrush areas along the grassy bottoms. This species and *Poa lucida* vie with each other for supremacy under such treatment.

A number of ranchers in the Rocky Mountain and Great Basin regions have recorded successful attempts at growing giant rye-grass (*Elymus condensatus*). The seed habits of this grass are good, but it is very coarse, and consequently in sections where there is a liberal supply of finer and less fibrous feeds it is not in favor. It is stoutly

maintained by ranchers in some sections that stock will not eat it, but the common experience of stockmen shows that cattle eat what they have to eat. In many sections it is a highly-prized species and is often cut for hay. It is very tenacious when thoroughly established and will grow in soil which is quite alkaline.

The list of native species which have been successfully used in reseeding or increasing the feed upon the range with a minimum of artificial treatment is small and confined almost entirely to the wheat and rye grasses previously mentioned.

CULTIVATED SPECIES.

There are a few species of cultivated forage plants which have been introduced successfully for the restoration and improvement of native pastures and meadows. In mountain meadows redtop (*Agrostis alba*) and timothy (*Phleum pratense*) are without doubt the most important. (See Pl. I, figs. 1 and 2.) There are many localities, especially in the Rocky Mountain and the coast ranges, where native sedgy and weedy vegetation has been very largely replaced by the judicious use of seed of these grasses. Remarkably good stands of both were to be seen in the Kootenai Mountains of Montana as early as 1897. These had been established by one or two seedings in late autumn with no cultivation whatever. Experiments in which the Department of Agriculture was interested conducted in 1897 with timothy in the Big Horn Mountains of Wyoming were successful in producing a decided increase in the yield of pastures at an altitude of 7,000 feet and also in creek bottoms at an altitude of 4,500 feet.

The experience of some of the most successful live-stock owners in the United States furnishes ample proof of the value of redtop and timothy in moist situations. Both with partial tillage and with no tillage these men have successfully sown seed in quantities of a ton upon moist meadows around Steins Mountains in eastern Oregon.

Some of the meadows established around the edges of the sinks above the alkaline soils by scattering the seed of redtop and timothy upon lands subsequently irrigated by spring flood waters have produced excellent permanent pastures of these two grasses, with little or no cultivation. In some cases where the grasses have been established along the upper courses of draws and creeks the seed has subsequently been slowly washed down the valley, producing gradually a decided change in the meadows of the creek bottoms. Throughout the Rocky Mountain region especially these two grasses are widely scattered, having become disseminated from hay and other horse feed hauled into the mountains, as well as by systematic effort. It is generally well understood that these grasses are most promising for reseeding ranges, and many ranchers have made more or less systematic attempts to introduce them upon private holdings.

In addition to these, red clover, white clover, and orchard grass have been used successfully in a more limited way in mountain meadows and upon cleared woodlands.

Fall planting will without doubt prove most advantageous in such situations on account of the difficulty of reaching the meadows early in the spring, as well as on account of the nature of the soil. It is a very noticeable fact that the ground dries out rapidly after the snows disappear in the spring in all the mountains of the extreme West and Southwest. The soil is very coarse and loose, and consequently dries out quickly. Sometimes the surface soil a few feet from a melting snowdrift is too dry for seed germination. Fall planting will then be most successful, for it will utilize the moisture to the greatest possible extent, causing the seed to germinate over the widest area possible. Care must be exercised to plant late in the autumn so that no germination will take place until spring. Seeding on the early snows is often a good practice, for then the seed, especially if it be timothy or alsike clover, is carried into the ground sufficiently to be covered. Redtop ought to be brushed or lightly harrowed, for its seeds do not cover as easily and are more likely to be blown away by the wind or to be washed away by the flood waters.

The methods employed in introducing these grasses into mountain meadows vary greatly. Sometimes the seed is scattered upon the snow; at other times it is sown in autumn on comparatively dry ground or in the spring upon wet ground as the snow melts. The efficiency of the different methods will depend largely upon the locality and the moisture conditions. On the whole, late fall seeding will prove most successful when no cultivation is practiced. Early spring sowing will, however, give good results if the ground remains moist enough for seed germination until the plants can become established. A great deal depends upon the altitude of the meadows to be seeded and the character of the soils of which they are composed. Harrowing with brush or with a spike-tooth harrow can usually be resorted to with profit, but further cultivation must be done with good judgment if the topography and soil are such that erosion is likely to occur. Good results have been secured from all methods. Even when sown upon sedgy meadows with no cultivation, timothy and redtop especially often supplant the native vegetation in very large measure, but usually the more sedgy portions remain permanently and the introduced grasses obtain control of the edges of the meadows in the more loose friable soils commonly found close to the willows, the redtop becoming more prevalent in the more moist situations.

Indeed, the willow lands in mountain meadows are well adapted to the growth of timothy. There are considerable areas which could be very much improved in the quality of their feed if shrubby willows were

removed and timothy and redtop sown. The soil in these situations is always loose, porous, and rich in humus, and is moist the greater part of the year, furnishing good conditions for the growth of these grasses. The growth of timothy upon willow lands, with little or no cultivation, is successfully carried on in the Okonogan Valley of Washington. Here it is a common practice to grub out the willow thickets and scatter timothy seed with no further preparation of the soil than to remove the willow stumps and leave the ground as smooth as possible. In two or three years with proper care a good timothy hay meadow is obtained. The same treatment would transform many mountain willow areas into much improved pastures or meadows.

The fact that the areas are subjected to inundations in the spring is not always prohibitive, for timothy withstands cold running water very well. Instances have come under the observation of the writer in eastern Oregon where timothy meadows have been flooded with shallow running water in the spring for a period of two weeks without apparent injury.

Any work upon the extension of mountain meadows by the removal of the brush about the edges must be done with rare judgment and care, for the conditions are such that the temporary destruction of the brush cover of these areas will often lead to erosive action that will destroy the entire meadow. This is especially true of many of the small meadows of the Sierra Mountains of California, where considerable work has been done by the Department of Agriculture. (See Pl. II, fig. 1.) Here it would be hazardous to destroy even the sedge turf, for it is underlain by a soil that erodes easily. In many cases plowing would result in an erosion that would drain and completely destroy the meadow. Supplanting the sedgy vegetation, which is of less value, by easily introduced species which will furnish more feed with little or no cultivation is to be recommended in such situations.

Redtop is of more importance in many places than timothy. It has the advantage of being adapted to moist situations. It is often difficult to determine whether a given meadow is better adapted to timothy or to redtop without a complete seasonal knowledge of the locality where the experiment is to be tried. Usually in every meadow some areas are better adapted to one than the other, and consequently the use of both in the improvement of native meadows is to be recommended.

Redtop commonly does not make a showing as soon as timothy, but it lasts longer and gradually drives out the latter on all soils to which it is adapted. Its ability to extend its distribution by means of running rootstocks gives it an advantage. Of course it is not to be expected that either of these grasses will produce immediate

results when sown among native vegetation in this way without cultivation. The results come gradually. It is really a remarkable thing that cultivated plants should be able to compete at all with native vegetation in its native habitat. Redtop is more difficult to establish than timothy, mainly because of the difference in their seeds, the seeds of the latter being more easily covered than those of the former. Covering the seed is much more important with redtop than with timothy. If no cultivation is given redtop should be sown in the fall just before the first snows come, and this is probably the best time, all things considered, for timothy seeding as well. This is doubtless the surest way to get the seed into the ground sufficiently for germination to take place. Owing to the difficulty of judging accurately the areas which are best adapted to each crop, it is advisable to sow a mixture of timothy and redtop. The first will make a showing earlier than the latter, but, especially in the moister situations, will eventually be supplanted by it.

Kentucky bluegrass (*Poa pratensis*), a distinctive pasture grass, is exceedingly aggressive and is adapted to and is becoming firmly established in the eastern edge of the cattle country. It is working westward into the western plains region. (See Pl. III, fig. 1.) Its spread is due to no intentional assistance from man, but it is spreading, nevertheless, very rapidly under the grazing conditions obtaining in this region. The indications now are that all of the small draws and ravines of native pastures far into western Kansas and Nebraska will eventually be largely taken by this grass without any assistance. Farther east, in the brushy regions of Arkansas and Missouri, it spreads rapidly under the influence of such grazing as will keep in check the more aggressive native grasses and brush, and indeed is now the main pasture grass over large sections of this region, so firmly has it become established.

It is entirely practicable to assist the spread of Kentucky bluegrass by seeding it upon uncultivated land. It should not be expected to furnish full stands in a short time. Indeed, it will take two, three, or four years to get a stand in favorable regions, and a proportionally longer time in other situations where the conditions of rainfall are less favorable. On the whole, fall seeding will probably give the best results, and light harrowing with a fine-tooth harrow will add to the success obtained. When there is sufficient rainfall in autumn to germinate the seed it will be profitable to sow then, if it can be done early enough to allow the grass time to become thoroughly established before the ground freezes; if not, then it should be seeded too late in the fall for germination during that season. In the western prairie States when it is desirable to supplant the native vegetation by bluegrass, the attempts should be first made in favored localities in creek

and river bottoms and in draws and ravines where the lands are heavier and the moisture more abundant than upon the uplands. In central Kansas and Nebraska, and especially eastward, conditions are more favorable for success on the uplands still used for pasture purposes.

On the whole, some of the standard forage plants mentioned have produced more permanent benefit in the improvement of native pastures and meadows than either of the other two classes. Their application, however, is limited to the conditions described.

INTRODUCED WEEDY SPECIES.

In certain sections of the United States aggressive annual plants have supplanted in a great measure the native vegetation and now furnish a large part of the feed on the uncultivated lands. Striking examples are found over large areas of California and Arizona and in the Columbia basin where the introduced plants are often much more abundant than the natives.

It is a noticeable fact, however, that all of these introductions were purely accidental. All of the annual introduced weedy plants which are so prominent and many of which are so important from a forage standpoint in the floras of the regions mentioned have been introduced without conscious effort, although by the agency of man.

Most prominent among these is alfilerilla, which is supposed to have been introduced from the Mediterranean region of Europe, but which apparently finds a more congenial home in America than in its original habitat. It is now found in both high and low altitudes of western America from the Canadian border to the hotter regions of southern Mexico. It is only in limited localities, however, that it has gained prominence. The conditions necessary for its best development appear to be mild, moist winter weather. Such conditions are furnished in portions of California especially. In southern Arizona the winters are mild enough, but the moisture is often lacking or improperly distributed, so that the crops produced fluctuate greatly. In some seasons small crops of hay of this plant may be cut in favorable desert areas, but usually it furnishes but indifferent grazing. The crop of the spring of 1906 was the heaviest ever known. Its range of adaptability is shown by the fact that it matures in April upon the levels of the Salt River valley, while it may not mature until June upon the higher levels of the Colorado slope of the San Francisco Mountains. (See Pl. III, fig. 2.)

No experiments yet conducted have been successful in introducing alfilerilla upon the ranges and having it care for itself and spread with any degree of rapidity, although many attempts have been made. Seedings made in the Santa Rita Mountains in the summer of 1906

germinated quite well the following winter, the first time, it is believed, that even this much has been definitely accomplished. The plant has, however, been spread apparently by sheep, and some ranchmen have made systematic efforts to spread it by methods of grazing, but there is very little, if any, definite knowledge at present as to the best way to handle the plant. The probability is that if seed is secured and scattered before a favorable season, success may be had in spreading it. The main consideration is to scatter the seed before a season favorable to its germination.

Wild oats (*Avena* spp.), of which there are two species of importance in California, forms, with alfilerilla, the most important feed in many sections. Like alfilerilla, little success has been had in attempts to spread either of the species on the range, although one of them occurs in abundance in cultivated lands in many sections of the United States and in other parts of the world. One of the species is sometimes found in the Huachuca, Santa Catalina, and other mountains of southern Arizona. Seed sown in the Santa Rita Mountains germinated in the winter of 1907 for the first time, although it was sown there on several previous occasions. Seeding with this grass will succeed better when it is covered with a harrow.

Besides the grasses previously mentioned there is a group of brome-grasses (*Bromus* spp.) which have become exceedingly abundant in the Pacific coast country. These species furnish, on the whole, rather poor feed, but on account of their aggressiveness they are of a great deal of importance. The feed is of low grade for several reasons. These grasses mature in early summer and like nearly all annuals are of low nutritive value after maturity. The seeds of some species are very annoying to stock, especially sheep, and even when young, green, and succulent, the plants are pulled up by the roots and are consequently not easily grazed by stock. These brome-grasses have invaded the coast territory by the assistance of man, but in spite of his conscious intentions. While they furnish considerable feed, it is not only of an inferior quality, but some of the species cause considerable direct injury through crowding out plants of more value. (See Pl. II, fig. 2.) The shepherd has to remove his flocks from the tucolote (*Bromus maximus*) areas of California when the seeds ripen, on account of the injury done to the feet, mouths, and eyes of his flocks by the sharp-pointed seeds of these grasses. On the whole, it is doubtful whether the introduction of this species has not been a positive detriment to the stock interests of California. The crowding out of other plants and the injury done to stock in many cases at least more than counterbalance the value of the feed produced by it. In the same category with tucolote may be mentioned wall-barley (*Hordeum murinum*) which, when

properly handled, makes a fair quality of hay and pasture, but is troublesome in meadows if allowed to mature before being cut.

To this group of aggressive weedy annuals belongs the Russian thistle, which is such a menace in the prairie States upon cultivated lands. In portions of the Southwest, especially along the Santa Fe Railway in New Mexico and Arizona, it is spreading rapidly. While it is pernicious in the cultivated plains regions mentioned, it adds somewhat to the forage supply and probably interferes very little with valuable native species in the arid regions of small forage production.

CHARACTER OF SEEDING DEPENDENT UPON NATURE OF REGION.

To one who is familiar with the range country in general there are evident principles involved which can not but be recognized as fundamental in introductions of grasses of the kind considered in these pages.

The introduced plants which have become conspicuous upon uncultivated sodded lands of this country are much less numerous than those which have become established upon unsodded lands. The plants which establish themselves in each section differ very radically in their habits of growth.

The only introduced forage plant which has become at all conspicuous and aggressive in the prairie States in competition with the native plants is Kentucky bluegrass, which is a perennial and spreads of its own accord by running rootstocks rather than by seed. The plants which have become established in the unsodded, uncultivated Southwest and in the Columbia Basin are annuals requiring but a short period of growth for their development and having good seed habits. The Russian thistle, some of the mustards (*Sisymbrium* spp. and *Brassica* spp.), and other weeds are well established in cultivated fields, but they do not compete at all with native species. They persist in neglected fields and upon the prairies to some extent, but only in gopher knolls and other partially cultivated situations. They do not compete with the native vegetation on untouched prairie soils. On the other hand, no introduced perennials have become established and aggressive upon the unsodded soils of the Southwestern States. The nearest approach to their establishment is in the case of Bermuda grass (*Cynodon dactylon*) and Johnson grass (*Sorghum halapense*), but they become conspicuous only in favored localities and mostly in cultivated or partially cultivated fields and moist situations which are capable of being, if not actually, sodded.

It seems, therefore, that the plants which have the best chances of becoming established without cultivation in the unsodded southwestern soils are what are termed weedy annuals with good seed

habits. As illustrations may be mentioned those which have become conspicuous over large areas, such as the brome-grasses, wild oats, and alfilerilla. The chances of introducing plants which will become aggressive on uncultivated sodded lands are much less than on unsodded areas.

The two types of regions discussed in these pages are so entirely different in their vegetative characteristics that it is difficult even to compare them. One has normally a ground cover with a thick mat of plant roots in the greater part of the surface soil, while the other is very largely devoid of vegetation. During a portion of the year in the latter situations the vegetation is less dense and usually occurs in scattering bunches when perennial, with considerable vacant space between; and when annual it produces a very irregular crop, which grows only in favorable situations in normal years. The regions which are largely devoid of vegetation, it would seem, are better adapted to the growth of annual plants whose seeds may fall upon unoccupied areas and by their special contrivances for planting themselves become incorporated with the soil without the interference of grass and other roots which occur in a sodded region.

Again, the unsodded Southwest, unlike the sodded northern plains, has different relations between its seasons of moisture and heat. The moist winter seasons here admit plants which will grow at comparatively low temperatures. The moisture is of such short duration that plants must pass through the vegetative state and mature seed in a comparatively short time, or else they will be destroyed by the following drought. Ordinary herbaceous plants (valuable under grazing) are therefore more likely to be annuals here than perennials, for it is only those which have some special contrivance for water reserve that are able to withstand the hot dry season. The balance between conditions which produce annuals and those which produce perennials is, however, apparently slight. Upon low desert mesas may be found shrubs and annual plants almost entirely, while in the foothills, at slightly higher elevations, perennials and shallow-rooted plants, such as grasses, are abundant, although seldom producing even the semblance of a sod. The soil conditions are also decidedly different in the sodded and unsodded regions, which, without doubt, has a marked influence upon the nature of the turf. In the unsodded areas the soil is much younger, generally coarser, and lacking in humus.

BURNING NATIVE PASTURES.

There are certain regions where the burning of native pastures at regular intervals has been practiced for many years with apparently little injury. Indeed, there appears to be but little question that

this practice has been beneficial in some instances, though it would be most unfortunate in the present range regions. In some of the Eastern and Southern States, especially where the brome sedges (*Andropogon* spp.) are an important factor in the vegetation of old, permanent, and native pastures, it is doubtful whether any other method of handling would prove as productive. These grasses produce strong, wiry, branching culms in late summer, which if left unburned or uncut would make it nearly impossible for stock to secure the young growth in the spring, while the growth of the previous year is of no value.

As far west as central Kansas it is a common practice to burn pastures periodically. So far west, however, this practice is very questionable because of the large numbers of other grasses which are injured by such treatment. The gramas (*Bouteloua* spp.), which are an important constituent of native pastures, from the eastern line of the Dakotas westward especially, are very readily injured by burning, especially when the ground is dry, as it usually is in autumn in this region. It is a matter of common observation that native pastures where this practice obtains which have been repeatedly burned are very much reduced in the quantity of blue grama (*Bouteloua oligostachya*) which they produce, while the broom sedges (*Andropogon* spp.) produce as well as ever unless the pastures have been much overstocked. When burning is practiced it should be done when the ground is moist or frozen, so that as little injury as possible may be done to the roots of the grasses. The practice is a necessary evil at best. Mowing should be resorted to in removing the old dead stems of the species of Andropogon in preference to burning whenever it is possible.

The burning of native pastures has no application to the general open range country.

CULTIVATION.

Considerable has been written concerning the beneficial effects of cultivation upon native pastures, but the practice has no application except upon small pastures in productive regions. A pasture requiring 20 acres to support a mature bovine animal for one year can not be profitably given even a light cultivation. Whether lands are benefited by a light harrowing or disking depends entirely upon the nature of the soil and the grasses composing the native vegetation. Loosening the soil lightly with a disk or fine-tooth harrow has been proved to be beneficial in the prairie States of South Dakota, Kansas, and Nebraska, and in other States farther east. Upon unsodded territory in Arizona, where the Department of Agriculture in cooperation with the Territorial University has experimented for several years along this line, disking has proved actually detrimental. A large part

of the sparse perennial vegetation was destroyed by the disking, and this effect was noticeable for about two years. The plants which escaped killing by the disk were larger than common, but there was really less feed produced the succeeding season than on uncultivated lands adjoining. The use of a fine-tooth harrow on these lands produced a slightly increased yield, but not enough by any means to pay for the labor. The fine-tooth harrow loosened the soil slightly without destroying the vegetation.

In a large section of the prairie region, from the Dakotas southward, ground allowed to run back before the sod has been thoroughly subdued invariably comes up to a very greatly increased stand of western wheat-grass (*Agropyron occidentale*) without any seed being sown. Disking here always produces increased yields of grass, and the pastures being small and productive, the increase will compensate for the expense. Some experiments conducted by the Kansas Agricultural Experiment Station show conclusively the benefits to be derived from the cultivation of native pastures in the vicinity of Manhattan.

Mr. W. J. Tod broke a 60-acre piece of prairie of raw blue-joint (*Andropogon* sp.) in March, 1884. That same season he took off a small crop of millet. In the autumn the ground was back-set and seeded to clover, timothy, bluegrasses, and orchard grasses. It is well known that breaking land in March in this region does not kill native grasses well. The result was that although the tame grasses supplemented the native feeds for a number of years—and persist even yet—it was the native grasses that were especially improved by the cultivation. It is estimated that this area has produced ever since an average increase of 50 per cent in forage over the untouched land surrounding, and people who put up hay for hire in the vicinity are willing to harvest this area for 25 cents a ton less than the surrounding country. But this region is productive. The land will support continuously and maintain its productiveness at the rate of one bovine animal to 4 acres for the summer grazing season. Here grazing is carried on during the summer season only, for the grasses do not cure well on account of the fall rains. In such a region the cultivation of lands held in native pasture can be made profitable. Indeed, a gain of 50 per cent can often be made, but, as stated, when the carrying capacity is low partial cultivation will not pay.

In a large part of the range region cultivation is actually impossible owing to the roughness or stony character of the country. In some sections the soils are so sandy that loosening them would cause drifting. Again, in some mountain meadow regions the soil is of such a nature that it is likely to be washed badly when once the surface is disturbed.

WEEDS IN NATIVE PASTURES.

In connection with native pastures the term weed is of very uncertain meaning, for what is considered a weed in one section is often a valuable forage plant in another. It is a common saying upon the stock ranges that a steer will eat what he is obliged to eat. As an illustration may be mentioned the Mexican poppy (*Eschscholtzia mexicana*) of the Southwest. This would scarcely be considered a forage plant of any value whatever by one unfamiliar with southwestern conditions. However, one can not but be impressed with the amount of feeding done upon it by stock in southern Arizona. In the vicinity of a large inclosure in the Santa Rita Mountains this plant is grazed to the ground by cattle, while it grows to a foot or more in height in the protected area and can be recognized within this area by the brilliant color of its bloom thirty miles away. It would ordinarily be considered of some value as a sheep feed, but it is not a weed in relation to cattle by any means.

In productive native pastures of the Middle West or the central plains region certain plants, mainly of the golden-rod and sunflower families, often become quite troublesome in overgrazed areas. In the North these are represented by the golden-rod (*Solidago rigida*); farther south by several species of golden-rod and sunflower; and from Oklahoma southward into southern Texas by the broom-weed (*Amphiachyris drachunculoides*). These plants assist in the demands made for burning pastures in some sections spoken of elsewhere; but a more effectual way of handling them is to mow them when in early bloom. This is extensively practiced in Kansas and Nebraska with good results. The plants here mentioned, which stock will not eat, are all natives which become troublesome under the artificial conditions brought about by handling stock upon native lands. There are but few introduced weeds which are common upon the stock ranges that are decidedly injurious. The brome-grasses, alfilerilla, wild oats, and others have been mentioned as being of decided value. Even the Russian thistle (*Salsola kali-tragus*), originally introduced into the prairie region where it never becomes troublesome in native pastures, is spreading in northern New Mexico and Arizona, but it is of some value upon these desert lands. In mountain regions there are several perennial weeds which do considerable damage and appear to increase with constant grazing. As examples may be mentioned dandelion (*Taraxacum* sp.), false hellebore (*Veratrum* sp.), yarrow (*Achillea* sp.), flag (*Iris* sp.), and *Wyethia* sp. Even some of these are of some value as sheep feed. These all grow in mountain pastures and high valleys. Some of them can be handled by breaking up the ground and sowing to timothy and redtop. Others grow on lands which can not be cultivated, and it is doubtful whether they can

be reduced by any practicable economic methods. On the edges of mountain meadows where the moisture is sufficient cultivation can be applied with economic benefit where the lands are under private control.

To be brief, what can be done depends upon the locality and the conditions. In favored localities it will pay to resort to some of the methods mentioned in the preceding pages. Where the carrying capacity of the lands is low no methods of eradication of weeds will pay for the labor involved. All that can be done is to get out of the land all that it produces of valuable plants without the abuse of overgrazing and to utilize the weeds if it can be done, if not by cattle then possibly by sheep or goats. It must be borne in mind that the really troublesome range weeds are few in number and locally distributed and that a large percentage of the feed upon the stock ranges to-day is produced by weeds.

SUMMARY.

(1) The introduced forage plants which have thus far become important upon range pastures in this country are few in number and without exception accidental in introduction.

(2) Profitable partial cultivation of native pastures must be confined to productive areas in regions of sufficient rainfall to permit at least the occasional cultivation of some of the hardier crops.

(3) The areas where reseeding methods on an economic basis are applicable extend to the western plains and are scattered throughout the mountains in meadows, high valleys, and other situations where the requisite moisture occurs.

(4) Care should be exercised in the cultivation of moist mountain meadows lest the breaking of the turf should result in destructive erosion.

(5) The most promising forage plants for the improvement of native pastures are Kentucky bluegrass as far west as the western plains region and as far south as the Bermuda and Johnson grass lands, and timothy and redtop for mountain meadows, high valleys, and other favorable situations having a loose friable soil containing a good supply of humus. Red, white, and alsike clovers and orchard grass are of value locally. These can be established with a minimum of cultivation. Seed may be sown either in late autumn or as the snow goes off in the spring.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Improved and unimproved native meadows in northeastern California. Fig. 1.—Timothy and redtop established without cultivation in one of the high valleys of northeastern California. Fig. 2.—An unimproved valley similar to that shown in figure 1. If the willows were cleared off and timothy and redtop sown they would take possession up to the sagebrush shown in the foreground.

PLATE II. Central California ranges. Fig. 1.—A sedgy, weedy mountain meadow where timothy and redtop will succeed, but the turf must not be destroyed, for erosion would completely drain the meadow. Fig. 2.—Foothills where introduced brome-grasses have taken possession. Some of these are valuable; others are really an injury to the range.

PLATE III. Native pastures in Kansas and Arizona. Fig. 1.—A native pasture in central Kansas where Kentucky bluegrass is gradually taking possession. It appears first in such draws and depressions as are shown in this illustration. Fig. 2.—A native pasture in Arizona during a favorable season. Mexican poppy and Indian wheat make a good growth. Alfilerilla is spreading here gradually of its own accord. Experiments thus far have failed to produce economic results here.

FIG. 1.—TIMOTHY AND REDTOP ESTABLISHED WITHOUT CULTIVATION.

FIG. 2.—AN UNIMPROVED VALLEY SIMILAR TO THAT SHOWN IN FIGURE 1.

IMPROVED AND UNIMPROVED NATIVE MEADOWS IN NORTHEASTERN CALIFORNIA.

FIG. 1.—A SEDGY, WEEDY MOUNTAIN MEADOW WHERE TIMOTHY AND REDTOP WILL SUCCEED.

FIG. 2.—FOOTHILLS WHERE INTRODUCED BROME-GRASSES HAVE TAKEN POSSESSION.

CENTRAL CALIFORNIA RANGES.

FIG. 1.—A NATIVE PASTURE IN CENTRAL KANSAS WHERE KENTUCKY BLUEGRASS IS GRADUALLY TAKING POSSESSION.

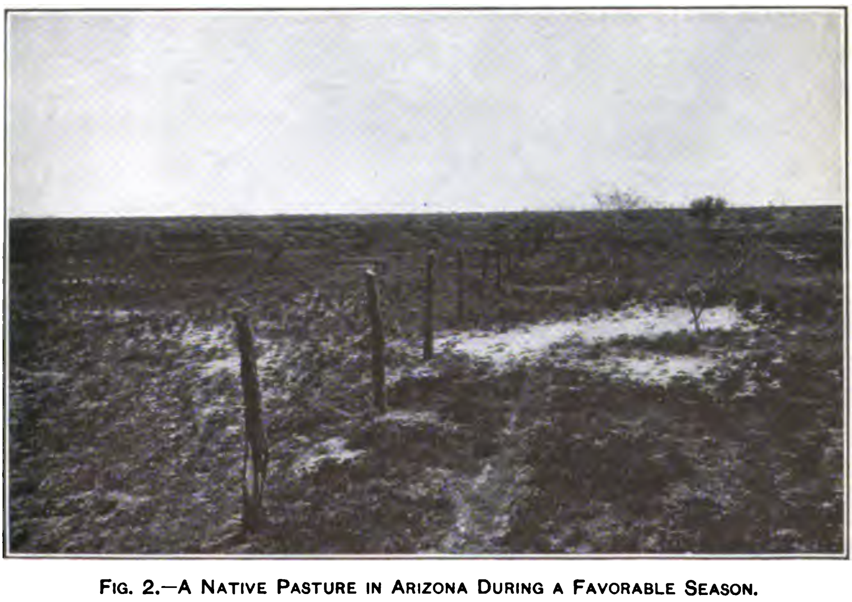

FIG. 2.—A NATIVE PASTURE IN ARIZONA DURING A FAVORABLE SEASON.

NATIVE PASTURES IN KANSAS AND ARIZONA.

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PERUVIAN ALFALFA:

A NEW LONG-SEASON VARIETY FOR THE SOUTHWEST.

BY

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PHYSIOLOGIST, IN CHARGE OF CLOVER AND ALFALFA INVESTIGATIONS, PLANT LIFE HISTORY INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., September 26, 1907.

SIR: I have the honor to transmit herewith, and to recommend that it be published as Bulletin No. 118 of the series of this Bureau, the accompanying manuscript, entitled "Peruvian Alfalfa: A New Long-Season Variety for the Southwest." This paper was prepared by Mr. Charles J. Brand, Physiologist, in charge of Clover and Alfalfa Investigations, Plant Life History Investigations, and has been submitted by Mr. Walter T. Swingle, Physiologist in Charge, with a view to publication.

The parent seed on which practically the whole alfalfa industry in the United States is based was originally imported from Chile, but comparatively few experiments have been conducted with alfalfa of South American origin. In the present paper Mr. Brand describes an alfalfa from Peru so different from the one commonly grown as to constitute, in his opinion, a distinct botanical variety. This new form is of great promise from a practical point of view, because it not only has a longer growing season, but recovers more quickly after cutting and grows to a larger size, hence yielding decidedly more than ordinary alfalfa.

Study of its life history requirements shows that it can be grown to greatest advantage only under irrigation and in the Southwest, where the climate is mild enough to permit its growth all winter.

Life history studies reveal and explain the weak points of new varieties of crop plants as well as their advantages. Mere variety tests do not usually give any explanation of the causes of success or failure and do not remove the danger of serious loss through attempting the culture of a new variety under conditions to which it is utterly unsuited.

Peruvian alfalfa is, for example, less harmed by frost than ordinary varieties and in the Southwest continues to grow throughout the winter. From this it might be supposed to be hardy, but on the contrary it proves in the Great Plains region to be the most tender alfalfa

known. Such results are mere paradoxes until explained by an understanding of its life history requirements and limiting conditions, which at the same time renders it possible to point out with confidence the only regions where Peruvian alfalfa promises to be superior to the sorts now commonly grown.

The experiments on which this bulletin is a partial report were inaugurated in 1904 and have been carried on under a cooperative arrangement between Plant Life History Investigations, the Seed Laboratory, and the Office of Seed and Plant Introduction.

The seed used in this work was sent to the Department of Agriculture by Mr. Adolfo Eastman y Cox, of Chile.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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PERUVIAN ALFALFA: A NEW LONG-SEASON VARIETY FOR THE SOUTHWEST.

INTRODUCTION.

Alfalfa continues to hold the attention of practical farmers throughout the United States, and a very large area of land is annually devoted to this plant, which is indeed the staple crop of the irrigated lands west of the one hundredth meridian. For this reason, it seems desirable to publish promptly all observations of scientific or economic importance on the life history of alfalfa and its varieties.

LIFE HISTORY STUDY OF ALFALFA INAUGURATED.

The very great value of the alfalfa crop to a large part of our country, especially to those sections where irrigation is practiced, has resulted in the importation of seed from sources very widely separated geographically and having vastly different soil, climatic, and other conditions. The effort to find strains suitable for regions where the successful culture of this crop has not yet been established has also contributed to this result.

In 1904 a life history study of alfalfa was instituted in the Bureau of Plant Industry, which, although far from being completed, has already yielded some results of a sufficiently important and suggestive nature to make it advisable that they be placed at the disposal of both the farmer and the experimenter.

In the course of the investigations on which this paper is a partial report, about thirty regional strains of alfalfa have been kept under observation for three years. Among these there is one from Peru whose unusually rapid growth, quick recovery after cutting, and continued growth through the winter in favorable climates result in the production of one or two more cuttings of hay each year than are yielded by the alfalfa commonly cultivated. The present bulletin is a summary of what is known about this remarkable variety.

CONTINUOUS GROWTH OF THE PERUVIAN VARIETY THROUGHOUT THE WINTER IN THE COLORADO RIVER VALLEY.

One of the most striking facts and perhaps the most important one noted in reference to the Peruvian variety is its complete lack of hardiness in all northern localities. From Groom, in the Panhandle of Texas (lat. 35° 12′ N.), to Indian Head, Saskatchewan (lat. 50° 28′ N.), on an average at least 99 per cent of the plants of this variety have been winterkilled during the past three years. Other sorts of alfalfa used in these experiments also suffered in varying degree, but none so severely as the Peruvian variety. Some few of them, such as the hardy Grimm alfalfa from Minnesota, and that grown from seed produced in the Milk River valley in northern Montana, showed no injury to the stand from winterkilling during the same period. On the other hand, curiously enough, at Yuma and at Phoenix, Ariz., frosts sufficiently severe to prevent the growth of all other kinds except the Arabian had no effect on the Peruvian variety, which continued to grow throughout the winter and was on February 28, 1907, ready for its first cutting, having by that date attained a height of nearly 2 feet.

Alfalfa grown in Arizona from Arizona, Provence, Turkestan, and northern Montana seed had all ceased growing in the autumn practically with the first frosts, while the Peruvian, which had winterkilled so universally at northern stations, grew throughout the year. Thus we have the paradox of the hardier strains having their growth almost wholly interrupted by the mild Arizona winter, while a variety known to be sensitive to cold has grown continuously under these same conditions.

ZERO POINT OF GROWTH AS EXPLAINING HARDINESS OF ALFALFA.[a]

A consideration of the physiological causes underlying the condition described has led to the conclusion that the explanation for it must be sought in the difference in the location of the zero point[b] of growth in Peruvian and in ordinary alfalfa.

In the form under discussion the zero point of growth is unusually low; that is, its growth will continue despite unusually low temperatures. Practically all other sorts of alfalfa, and indeed almost all crop plants, stop growing before the minimum for this variety is reached. The direct consequence of this low zero point under the climatic conditions that prevail in the Colorado River valley near

[a] The explanation of hardiness here published for the first time was suggested to the writer by Mr. Walter T. Swingle in the course of a discussion of the life history requirements of Peruvian alfalfa.

[b] The zero point of growth of any variety may be defined as the minimum temperature below which growth ceases.

Yuma and in the Salton Basin is continued growth of the Peruvian alfalfa throughout the winter season, although the cold is sufficient to prevent activity in practically all other varieties.

EFFECT OF LOW ZERO POINT UNDER UNFAVORABLE CONDITIONS.

In colder regions the low zero point results in the plant being unaffected by the cool weather of the autumn, which in the case of other varieties of alfalfa first merely retards growth and finally arrests it altogether.

Because of its low zero point, Peruvian alfalfa does not cease growing in the autumn, and as a consequence it is caught with tender growth and killed by the first severe freeze, while other alfalfas, having gone into the resting stage, are not harmed.

PRACTICAL SIGNIFICANCE OF LOW ZERO POINT UNDER FAVORABLE CONDITIONS.

The most obvious advantage to a plant of a low zero point under favorable conditions is that growth continues long after it has ceased in plants having a high zero point. In the Salton Basin, in the Colorado and Salt River valleys, and in other sections which have mild winter weather, the Peruvian variety makes a very considerable winter growth, while the other alfalfas make practically none. (See fig. 3.) This winter growth furnishes valuable pasturage for cattle and hogs and food for poultry, or if allowed to remain on the field results in the production of an extra crop of hay, thus increasing the yield to the acre from 15 to 20 per cent each year.

Inasmuch as green alfalfa is the food preferred throughout the year for ostriches, this strain and, in a less degree, the Arabian have a decided advantage over all others for ostrich farming, which is becoming an important industry in the very region to which this alfalfa is best adapted.

There are high valleys in New Mexico, Arizona, and Colorado, where the winters are mild, to which Peruvian alfalfa may prove to be adapted. It is also possible that this form may be as hardy as any other in sections where the approach of cold weather is gradual enough to force it to suspend growth before winter arrives.

It is evident from the foregoing that the possession of a low zero point is a great advantage under favorable conditions and an equally great disadvantage under unfavorable conditions. Hence this factor must be given consideration before it can be determined into what regions alfalfa may be introduced with profit.

PROBABLE LOCATION OF THE ZERO POINT OF PERUVIAN ALFALFA.

Inasmuch as complete weather records are available for Yuma, a careful study of these has been made in the hope of determining, approximately, the zero point of Peruvian alfalfa. The experimental

plats are located but a few hundred feet distant from the Weather Bureau station. An examination of the records shows that the mean temperature for the months from October, 1906, to February, 1907, inclusive, was 61.8° F. Considerable growth was made throughout this period. The lowest monthly mean was 53.8° F. for January. During this month less growth was made, but it was not entirely interrupted. From this it would appear that under the given conditions the zero point is located somewhere below 53° F. However, according to the records for the Arizona Experiment Station, the mean for the same months at the station farm near Phoenix was 57.7° F., the lowest monthly mean being 50.7° F. for January, 1907. Here also growth was made during the winter months, including January, with a mean a little more than 50° F. Hence it is evident that the zero point of the Peruvian variety is below 50° F., probably

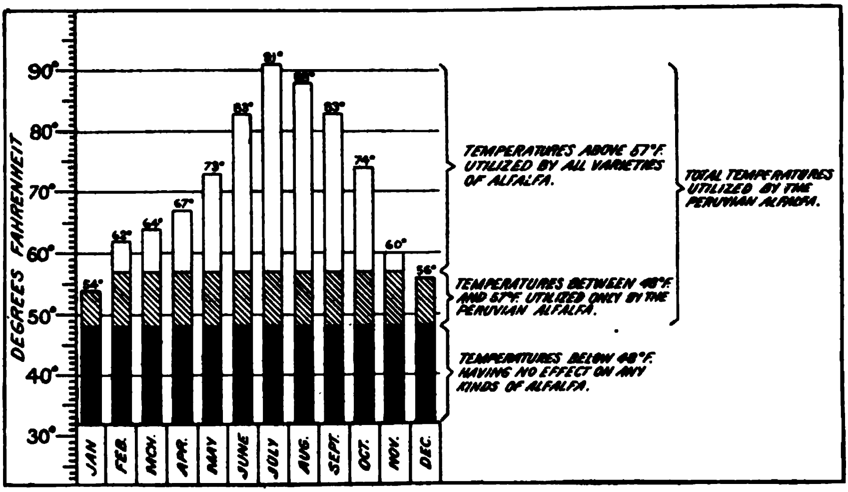

FIG. 1.—Diagram showing the monthly mean temperatures for 1906 at Yuma, Ariz., and their utilization by Peruvian and by common alfalfas.

about 48° F., while that of the common form lies between 53° F. and 61° F., perhaps at about 57° F. In any case it is hard to locate the zero point accurately, especially for ordinary alfalfa, on account of the disturbing factor introduced by the direct action of frost in killing the leaves.

The accompanying diagram (fig. 1) shows graphically the advantage which the low zero point gives the Peruvian over the ordinary kinds. The mean temperature for each month during 1906 is represented by a column. The solid base extending from the freezing point to 48° F., the approximate zero point of the Peruvian variety, represents the temperatures which have no effect on any kinds of alfalfa; the cross-hatched portion between 48° F. and 57° F., the estimated zero point of ordinary alfalfa, shows the temperatures

which can be used by this variety only, while the part of each column above 57° F., and extending up to the mean for each month, represents the temperature utilized by other alfalfas as well as the Peruvian. All temperatures above the solid bases of the monthly columns are utilized by the Peruvian, while only those above the cross-hatched portion are used by the ordinary strains. The additional heat units available on account of the low zero point explain, in a measure, the more rapid growth of this new form.

The chart shows that in December and January, when considerable growth could be made by the Peruvian alfalfa, none whatever was possible by any other variety, because the mean for both of these

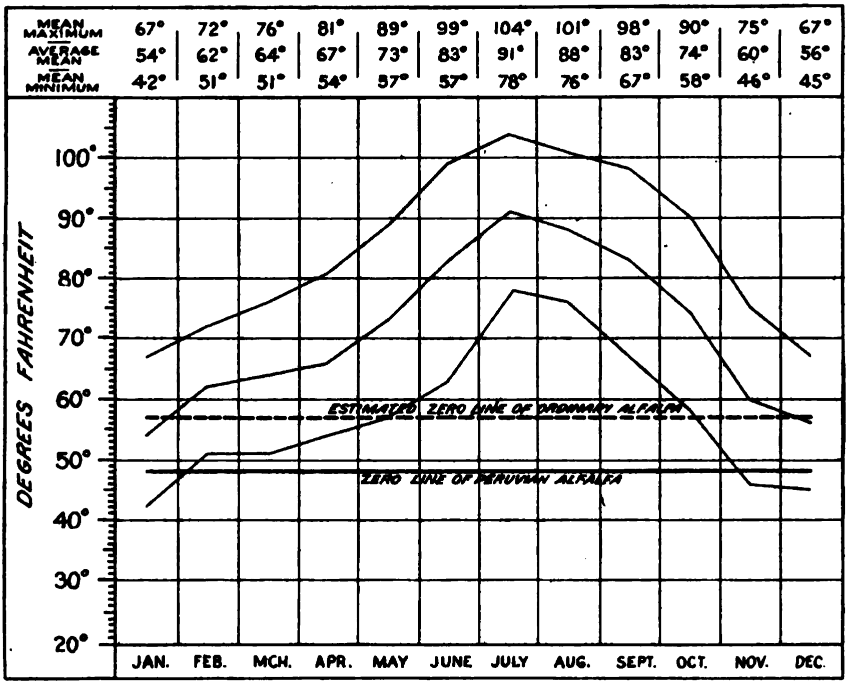

FIG. 2.—Curves representing the average maximum (upper curve), mean (middle curve), and minimum (lowest curve) temperatures for 1906 at Yuma, Ariz.

months was below the zero point of ordinary alfalfa. There was one exception to this, namely, the Arabian, which will be briefly discussed in a later paragraph. The zero point of this strain lies between that of the Peruvian and that of the ordinary alfalfa.

The diagram shows temperatures that might be used by ordinary alfalfa in both February and November. However, when frost occurs during these months, ordinary alfalfa is retarded and prevented from making full utilization of the available heat. Furthermore, it will be seen by reference to figure 2 that the curve representing the average of the minimum temperatures lies considerably

below the estimated zero point of common alfalfa during both of these months.

For convenience of expression mean temperatures above the zero point may be called positive and those lying below negative. The former, when long enough continued, stimulate growth, while the latter would seem at first sight to be merely useless. However, further observation goes to show that negative temperatures are actually harmful, as they prevent the complete utilization of available positive temperatures. Before growth can proceed after cold nights a warm sun for several hours is required to take off the chill.[a]

Only during January and December did the Peruvian alfalfa suffer from nocturnal chilling, and then but slightly, since only a small proportion of the temperatures for these months fell decidedly below its zero point for growth.

A further examination of figure 2 shows that the minimum curve for November, December, January, February, March, and April extends below the zero line of common alfalfa, while only during December and January does any considerable portion of the curve extend below the zero line of the Peruvian variety. This means that common alfalfa suffered retardation during six months of the year, while the Peruvian form was affected during but two, and then but slightly.

Coincident with the low zero point of the new form a low optimum might be expected, but this has not been found to be the case. Indeed, its optimum appears to be fully as high as that of any other alfalfa. An explanation of this fact is given later.

DIFFICULTY OF LOCATING THE ZERO POINT.

On the difficulty of locating the zero point, De Candolle,[b] who made extensive investigations on the heat requirements of plants, says:

> The most difficult points to fix are the minima. One is rarely in possession of such direct observations as to permit establishing them. One is then compelled to seek them by groping, through comparison between the different extreme localities where the species extends. I often succeeded in doing this in a more or less satisfactory manner. My investigations as a whole show one thing I was not thinking of while busy with the details, namely, that the minima generally rise in proportion as more southerly species are concerned.

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[a] Mr. Walter T. Swingle has called attention to this phenomenon in Bulletin 53 of the Bureau of Plant Industry, "The Date Palm and its Utilization in the Southwestern States." In the course of some studies on the date palm during October and November, 1906, at Tempe, Ariz., and Mecca, Cal., the present writer observed that when the night temperatures fell decidedly below 64.4° F., the conventional zero point for the date palm, no advance whatever was made in ripening during the succeeding day, although the maxima were often fully as high as on days when normal progress was made. In other words, warm nights were just as essential for the proper ripening of the fruit as were hot days.

[b] De Candolle, Alphonse. Géographie botanique raisonnée, Paris and Geneva, 1855, vol. 1, p. 395.

The present investigations do not bear out De Candolle's last statement, as in the Peruvian alfalfa we have a southerly form which has a decidedly lower minimum (i. e., zero point) than those from more northerly regions. This may be accounted for by the fact that alfalfa is an introduced plant in South America, and the variety under discussion has adjusted itself to the climatic conditions of high plateaus in an equatorial latitude.

Alfalfa was no doubt brought into Peru at the time of the Spanish conquest, more than three hundred years ago. During the long period that has since elapsed, a rigid though unconscious selection has probably gone on. Only those plants having a low zero point were able to produce seed, the sum of heat being insufficient to ripen the seed of forms having a high zero point.

The parent alfalfa which the Spaniards brought with them to Peru probably came originally from the hot deserts of the Old World. Millenia of growth in desert climates necessitating adaptation to withstand long, hot summers preceded the relatively short period of rigid selection already mentioned, tending to adapt the plant for growth at low temperatures. The high optimum temperature of growth of Peruvian alfalfa was probably developed during its stay in the Old World deserts, and it still persists after a few centuries of culture at high altitudes in the Andes. If grown long enough under conditions that do not call into use the ability to grow at high temperatures, doubtless the power to thrive in very hot weather would be lost, just as has been observed in the case of blind cave fishes whose sight organs became atrophied through disuse.

The possession of a low zero point by Arabian alfalfa [a] suggests that possibly the parent seed of Peruvian alfalfa likewise originated in a region where, in addition to hot summers, there were mild winters, during which growth was possible in plants having a low zero point. In this case the unusually low zero point of Peruvian alfalfa represents only the further development of a character already present.

Weather records for Peru, and indeed all South American countries, are unsatisfactory, but Hann [b] gives a rather complete summary for both Lima, Peru, and Quito, Ecuador. The mean annual temperature of Quito is 56.3° F.; the warmest months, December and January, have a mean of 56.66° F.; the mean of the coldest month is 56.32° F., the difference in mean between the coldest and the warmest month being only 0.34 of 1 degree. Any crop plant to succeed at all under such climatic conditions must have a zero point at least as low

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[a] See the discussion on pages 16 to 18, under the heading "Comparison of Arabian with Peruvian alfalfa."

[b] Hann, Julius. Handbuch der Klimatologie, 2d ed., Stuttgart, 1897, vol. 2, pp. 323–349.

as the mean monthly temperature of the warmest month—in this case 56.66°.

If it were not as low as this, there would not be sufficient heat to stimulate the plants into growth. On the other hand, a zero point considerably lower than this would be a distinct advantage, as the optimum temperature of growth lies considerably above the zero point.

The mean yearly temperature at Lima is 66.2° F. The mean of the warmest month, February, is 73.76° F.; of the coldest month, July, 58° F. The difference between the annual mean maximum and minimum is 15.76° F. This difference is much greater than that for Quito. However, the only place in the United States having so small a difference as this is San Diego, in southern California. Following is a table giving the mean temperatures for the year and for the warmest and coldest months at four places each in South America and North America. Temperatures are given in degrees Fahrenheit and altitudes in feet.

TABLE I.—*Comparison of mean temperatures of some South American and North American localities.*

Place.	Latitude.	Longitude.	Altitude.	Mean temperature in degrees Fahrenheit.					
				Annual.	Warmest month.	Month.	Coldest month.	Month.	Difference.
	° ′	° ′	*Feet.*						
Quito	0 14 S.	78 32 W.	9,350	56.3	56.66	Dec., Jan.	56.32	July	0.34
Lima	12 4 S.	79 21 W.	524	66.2	73.76	Feb	58.0	...do..	15.76
Guayaquil	2 10 S.	79 56 W.	(a)	76.6	83.3	Jan	77.9	...do..	5.4
La Paz	16 30 S.	68 10 W.	11,972	50.0	54.5	Nov	45.14	June	8.36
San Diego	32 43 N.	117 10 W.	40	61.0	70.0	Aug	54.0	Jan	16.0
Yuma	32 45 N.	114 36 W.	137	72.0	92.0	July	54.0	...do..	38.0
Washington	38 54 N.	77 3 W.	75	55.0	79.0	.....do....	33.0	...do..	46.0
St. Paul	44 58 N.	93 3 W.	758	45.0	74.0	.....do....	12.0	...do..	62.0

[a] Sea level.

A study of these data would indicate that alfalfas with a low zero point would do better than any others in such an even, cool climate as San Diego, and this will no doubt prove true, but the fact that the Peruvian variety does so well at Yuma demonstrates further that its maximum temperature (above which growth ceases) is considerably higher than the mean for the hottest month (94° F. in July) at Yuma.

COMPARISON BETWEEN AMOUNT OF GROWTH OF PERUVIAN AND SEVERAL OTHER ALFALFAS.

In order to illustrate more effectively the great diversity in the amount of growth made during the winter by different regional strains average specimens were selected from each of the plats on

the reclamation tract at Yuma, Ariz. Figure 3 shows (at one-fourth natural size) specimens grown from Peruvian, Arabian, Turkestan (Samarkand), and native Arizona seed.

These specimens in each case were selected to represent the average condition of the plats and therefore may be considered directly comparable. The plants from which the figures were made were collected about the middle of November, 1906. At that time the average height of the Peruvian variety was 24 inches and of the Arabian 19 inches, while that of the Turkestan and native Arizona alfalfas was 12 and 10 inches, respectively. Furthermore, practically all growth had ceased in the last two named. From this it is apparent that the Peruvian alfalfa was 5 inches taller than its nearest competitor, the Arabian, 12 inches taller than the Turkestan strain, and 14 inches taller than the plants produced from home-grown Arizona seed.

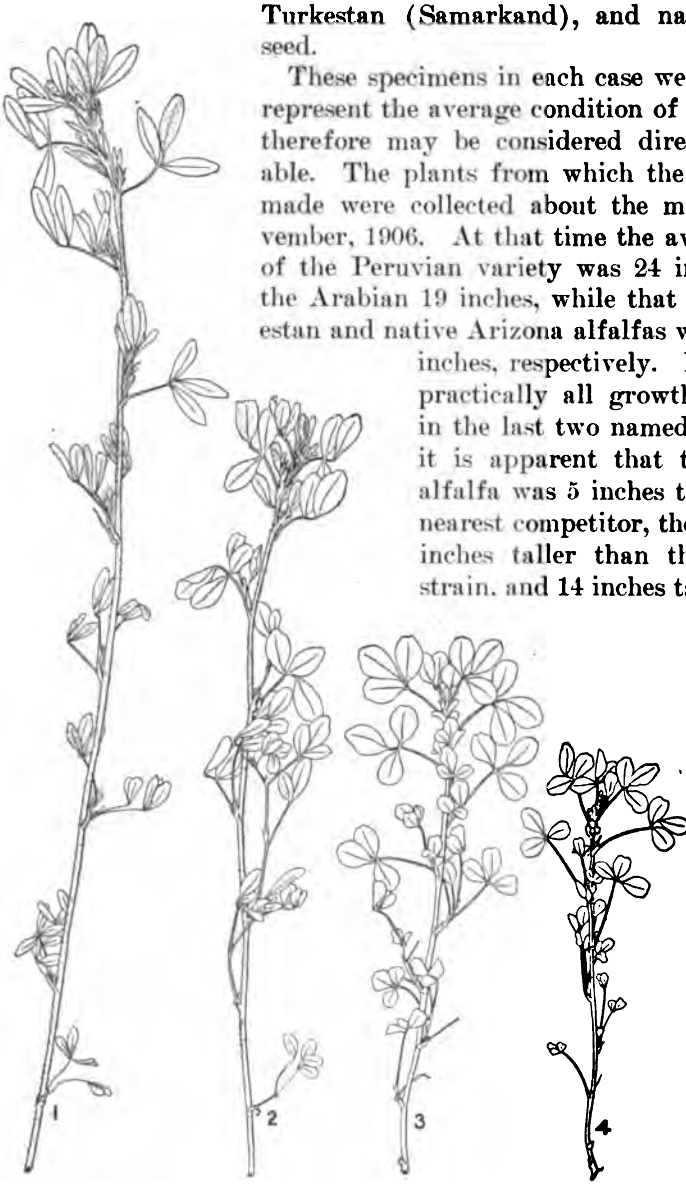

FIG. 3.—Comparative growth of various alfalfas: 1, Peruvian; 2, Arabian; 3, Turkestan; 4, Arizona. (One-fourth natural size.)

In the spring of 1907 these differences were even more marked, and on June 8 the average height of the Peruvian alfalfa was fully 3 feet, while none of the other strains averaged more than 2 feet. This difference is shown in Plate II, figures 1 and 2. The latter figure shows the well-known Oasis alfalfa (S. P. I.

No. 12846) of northern Africa, secured in Tunis by Mr. Thomas H. Kearney. The Arabian strain did not compare as favorably as in November, 1906.

COMPARISON OF ARABIAN WITH PERUVIAN ALFALFA.

Next to the Peruvian variety Arabian alfalfa has been found to have the lowest zero point. This interesting alfalfa was secured from Bassorah, Arabia, by Mr. David Fairchild, Agricultural Explorer. Several importations have been made from Arabia by Mr. Fairchild, and his notes concerning these, published in the inventories of the Office of Seed and Plant Introduction, deserve to be quoted in full:

8806. *Medicago sativa.* Alfalfa.

From Bassorah, Arabia. Received through Messrs. Lathrop and Fairchild (No. 904, March 15, 1902), June 7, 1902.

Djet. "This is treated like any alfalfa. (See No. 8823.) This is given a separate number as it comes from 500 miles south of the locality whence No. 8823 was sent. Secured through the assistance of Mr. Raphael Sayegh, of Bassorah." (*Fairchild.*)[a]

8823. *Medicago sativa.* Alfalfa.

From Bagdad, Arabia. Sent by Agha Mohammed, the Nawab at Kasimain and consular agent at that place for His British Majesty. Received through Messrs. Lathrop and Fairchild (No. 881, March 10, 1902), June 7, 1902.

Djet or *El-djet.* "A larger quantity of seed can be secured through arrangement with the American vice-consul at Bagdad, Mr. Rudulph Hürner. Although the Nawab admits this to be the best plant for horses he has ever grown, he says that he is the first in the region of Bagdad to grow it, and this, notwithstanding the fact that at Kerbella, only a day's journey away, large areas have been planted to it from ancient times. In the especially hot summers the fields are irrigated three times a month; in the cooler summers only twice. From 9 to 10 cuttings are taken each year, and the fields are manured with stable manure after each cutting. The life, i. e., profitable life, of a field of this *djet* is seven years. This variety should be admirably suited to our irrigated lands in California and Arizona, and deserves a trial in comparison with the Turkestan alfalfa. It should also be tested as to alkali resistance." (*Fairchild.*)[b]

12992. *Medicago sativa.* Alfalfa.

From Bassorah, Arabia. Secured through H. P. Chalk, esq., American consular agent. Received February 27, 1905.

"From preliminary tests of this alfalfa, made from a previous importation, under S. P. I. No. 8806, it seems probable that this particular strain will make a more rapid growth than the ordinary varieties cultivated in this country and

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[a] Seeds and Plants Imported During the Period from September, 1900, to December, 1903. Inventory No. 10. Bulletin No. 66, Bureau of Plant Industry, 1905, p. 227.

[b] Loc. cit., p. 229.

may prove especially valuable for certain regions in southern California and Arizona. These preliminary experiments have been carried on at the Pomona substation in California, where this variety, together with the ordinary and the Turkestan varieties, planted side by side at the same time, exhibited most unusual rapidity of growth." (*Fairchild.*)[a]

The writer has not seen plants of No. 8823, but in June of the present season (1907) saw on the California substation farm at Tulare a plat of the original importation (S. P. I. No. 8806) mentioned by Mr. Fairchild. This has the same characters as the more recently imported seed (S. P. I. No. 12992) used in the present experiments.

The comparative amount of growth made at Yuma by the (1) Peruvian, (2) Arabian, (3) Turkestan, and (4) home-grown Arizona alfalfa from the date of last cutting up to November 15, 1906, is shown in figure 3. At that time the Arabian stood next to the Peruvian variety. During the present season, the Arabian alfalfa, though still easily second, has fallen off considerably in growth. In rapidity of growth, also, the Arabian sort is intermediate between Peruvian and ordinary alfalfa.

The zero point of Arabian alfalfa is higher than that of the Peruvian and lower than that of common alfalfa; hence, it has a shorter growing season than the Peruvian and a longer growing season than common alfalfa. It has the same lack of hardiness as the Peruvian variety, and its plants are also quite hairy. Nevertheless, the two varieties are readily distinguished from one another. The most evident botanical difference between the two is to be found in the leaves. The leaflets of the Peruvian alfalfa are very long compared to their width, being from 3 to 5 times as long as broad. The forms having three and four leaflets, shown in figure 8, are typical of the Peruvian variety. The leaflets of the Arabian alfalfa are, on the other hand, very broad in comparison to their length, giving an impression of roundness. They range from 1¼ to 3 times as long as broad. The average width was found by measurement to be 13.6 mm. and the average length 27 mm.

In its floral characters the Arabian is much nearer the common form (fig. 4) than is the Peruvian alfalfa (fig. 5). The flowers are usually smaller; the long calyx teeth characteristic of the Peruvian form are not present, nor are the teeth as long in comparison with the calyx tube in the Arabian variety.

The low zero point of the Arabian strain may have been brought about by long-continued cultivation under a mild winter climate per-

[a] Seeds and Plants Imported During the Period from December, 1903, to December, 1905. Inventory No. 11. Bulletin 97, Bureau of Plant Industry, 1907, p. 121.

mitting growth by plants having a low zero point. Like the Peruvian, the Arabian alfalfa has a high optimum temperature, acquired no doubt by cultivation since almost prehistoric times in hot deserts.

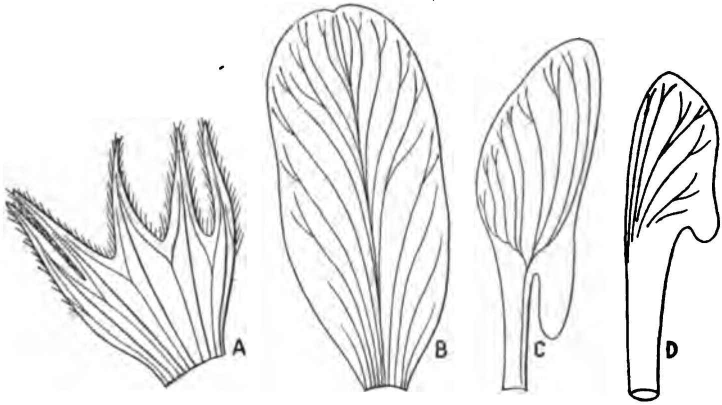

FIG. 4.—Floral parts of common alfalfa: A, calyx; B, standard; C, wing; D, keel. (Enlarged seven times.)

RECENT BOTANICAL HISTORY OF CULTIVATED ALFALFA.

The view that cultivated alfalfa is not one homogeneous species, but is composed of numerous strains, varieties, or even subspecies, requiring different cultural treatment, is a somewhat new one, but appears, nevertheless, to be correct.

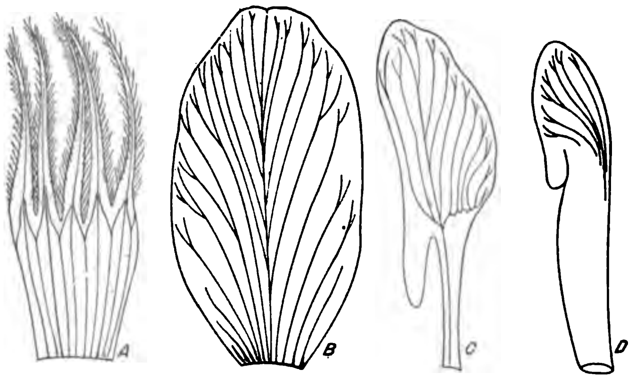

FIG. 5.—Floral parts of Peruvian alfalfa: A, calyx; B, standard; C, wing; D, keel. (Enlarged seven times.)

Alefeld,[a] in 1867, writing in Germany where alfalfa, or luzerne as it is there called, has been grown increasingly since 1573, having been introduced about that time from Spain through France, called atten-

[a]Alefeld, F. Ueber die Formen mehrerer Kulturpflanzen. Bot. Zeit., 25, 1867, p. 289.

tion to the now well-known fact that all cultivated plants vary extraordinarily on account of their being distributed by man into regions having far more diverse conditions than those to which they are subjected through the ordinary agencies of nature. However, he goes on to state that there is a very noteworthy exception to this well-nigh universal rule, namely, *Medicago sativa*, which was known to him in a large number of wild forms, but, despite its culture since remote antiquity, in only a single cultivated form.

In an earlier work Alefeld,[a] after a critical study of the wild forms alluded to above, most of which were collected in the Himalaya Mountains, described a number of new subspecies or varieties based on this material. All of these forms were placed in contradistinction to the cultivated one which he called *Medicago sativa vulgaris* ("gemeine gebaute Lucerne"), and regarded as one form with no varietal differences worthy of note.

Later, Urban [b] in his monograph of the genus Medicago recognized as valid Alefeld's classification of cultivated alfalfa in the subspecies *vulgaris*, and added one variety, *gaetula*, whose distribution is given as "only near Biskra, Algeria." Exact botanical knowledge of the forms of the cultivated plant has remained in practically this state until the present day. A few indefinite and imperfectly understood forms whose names are based largely on their geographical origin have in more recent times received a certain amount of acceptance.

By far the most widely known of these is the Turkestan alfalfa, sometimes loosely called the variety *turkestanica*, which has been imported in large quantities and has in some cases shown itself to be especially suited to particular sections of this country. As numerous distinct strains are comprised under this name, the variety has no botanical standing. Another form, specimens and seeds of which were sent from Tibet to Europe, has been called *tibetana* by Alefeld, *chinensis* by Werner, and by still other authors has been assigned to Alefeld's variety *rotundifolia*, to which Alefeld did not consider that it properly belonged. The foregoing represents approximately the present state of our botanical knowledge of cultivated alfalfa.

WILD FORMS OF MEDICAGO SATIVA.

Perhaps the most notable wild subspecies or varieties of *Medicago sativa* that have been described are *gaetula* and *tunetana*. These differ markedly from the variety discussed in this paper and all other cultivated forms in having glandular hairy pods and calyces.

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[a] Alefeld, F. Landwirthschaftliche Flora, Berlin, 1866, pp. 74–76.

[b] Urban, I. Prodromus einer Monographie der Gattung Medicago L. Verh. d. bot. Vereins d. Prov. Brandenburg, 15, pp. 1–85, 1873.

Gaetula, although Urban's original description [a] of it is very inadequate, seems to have purple flowers, while the *tunetana* of Murbeck [b] has yellow ones. Both are native to the plateaus and mountains of northern Africa.

The little-known *Medicago pauciflora* Ledeb. and *M. coerulea* Less. are placed by Urban with his still more imperfectly described *pilulifera* as varieties of his subspecies *microcarpa*, characterized as having very small flowers, 6–6½ mm. in length, and pods with only one-half to 2½ turns and only 3 to 3½ mm. in diameter. No fully open flower or ripe pods of ordinary alfalfa or the varieties *tunetana*, *gaetula*, or Peruvian alfalfa are ever so small, and they are usually from 1½ to 2 times the dimensions given. Indeed, such small flowers and pods can only be found in the most immature specimens. *Medicago falcata*, with Koch's variety *glandulosa* and *M. media*, have no similarity to Peruvian alfalfa or other forms of the true *M. sativa* L.

DIFFERENCES WHICH DISTINGUISH PERUVIAN ALFALFA.

Accompanying and possibly correlated with the physiological differences which have been discussed are certain other characters in the form and habit of the plants which serve to distinguish this variety from the common one, both in the field and in herbarium specimens.

In the field Peruvian alfalfa is so obviously different from the alfalfa ordinarily grown that it is readily possible to tell at a glance where the plats of Peruvian alfalfa end and those sown to common alfalfa begin. This is true even in cases where no alleyways intervene between plats and during the summer when the plants are in the same stage of development.

The Peruvian plants are, on the whole, taller, the stems less branched, and fewer stems arise from each crown. (Pl. I.) The plants are also large and if left too long uncut become very coarse and woody. They are vigorous, erect in habit, of rapid growth, and make especially rapid recovery after cutting.

Perhaps the one character by which this variety can be most readily distinguished is the pubescence which covers the whole plant, somewhat sparsely at the base, but becoming increasingly dense in ascending until at the top the plants are densely covered with minute downy hairs. The common variety is, on the other hand, quite smooth except for a very slight hairiness at the top. A field or plat of the latter has the typical vivid green, while a plat of the Peruvian variety

[a] Loc. cit.

[b] Murbeck, Sv. Contrib. flore de la Tunisie, etc., in Lunds Univ. Arsskrift, vol. 23, 1897, p. 62.

has a silvery grayish green. This gray color of the Peruvian alfalfa is due not only to the hairiness of the plants but also in part to the fact that the veins of the leaves are almost white.

The midrib and secondary veins of Peruvian alfalfa are broader than those of ordinary alfalfa. This is due to the presence of a wider strand of colorless water-storage tissue which makes the leaves appear a paler green than those of the common alfalfa. This tissue is also present in the leaves of ordinary alfalfa, but because of the narrowness of the veins does not noticeably change the appearance of the plants.

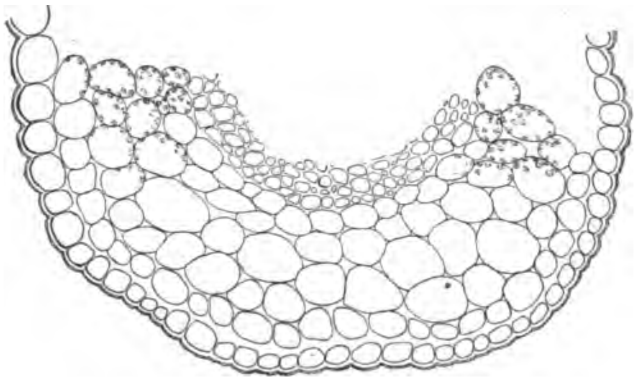

FIG. 6.—Cross section of midrib of terminal leaflet of Peruvian alfalfa, showing broad band of colorless water-storage tissue. (Magnified 240 times.)

Figures 6 and 7 show cross sections through the midrib of Peruvian and of ordinary alfalfa, respectively. These are magnified 240 times and show the dorsal epidermis and the water-storage tissue on the leptome side of the veins of the terminal leaflets.

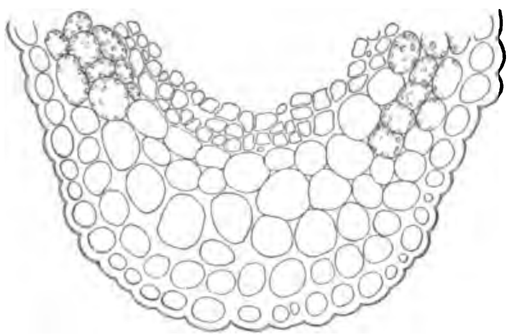

FIG. 7.—Cross section of midrib of terminal leaflet of ordinary alfalfa, showing narrow band of colorless water-storage tissue. (Magnified 240 times.)

The leaflets are rather long obovate, with wedge-shaped bases, and in primary leaves are practically all as long or longer than the leaf-stalks. The outer portion of the leaflets is toothed, the bases entire, and each midrib ends in a pronounced tooth. As compared with typical specimens of *Medicago sativa* the stalk of the middle leaf (petiolule) is very long in proportion to the main stalk of the whole leaf (petiole). More than fifty specimens of both forms were measured. In ordinary alfalfa the average length of the petiolule was found to be less than one-eighth the length of the petiole, while in the Peruvian variety it was more than one-fourth the length.

Many plants of the new variety have leaves with four, five, and even six leaflets, instead of the three characteristic of alfalfa. (See fig. 8.) Of nine specimens selected wholly at random from a field at Yuma four were found to bear some leaves having more than three leaflets. It seems probable that this character may bear some relation to the long petiolules referred to. The presence of numerous individuals showing this tendency furnishes an opportunity for improving the quality of alfalfa hay by increasing the proportion of leaves to stem material. It is believed that by careful selection a five or even a seven leafed type can be fixed, and selections are being made with this purpose in view. Should this result be obtained, another advantage will follow: While to a careful observer the plants of Peruvian alfalfa are obviously different from all others, the seed and young plants differ little, if at all. The additional leaflets would furnish an unmistakable mark of recognition that would tend to prevent the sale of adulterated seed to farmers at the high prices usually commanded by seed of a valuable new variety of a staple crop plant.

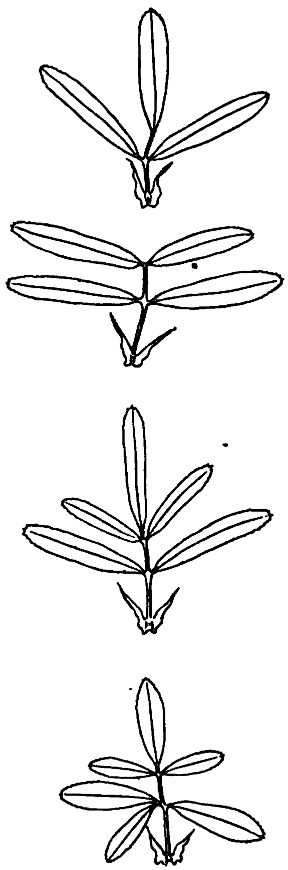

FIG. 8.—Three, four, five, and six leafed forms of Peruvian alfalfa. (One-half natural size.)

The flowers are generally longer than in ordinary alfalfa, some attaining a length of almost half an inch (12 mm.). Their characteristic color is plum purple, while in the common alfalfa it is violet. The calyx teeth are as long or longer than the calyx tube, longer than the pedicels—sometimes equaling in length the keel. (See figs. 9 and 10.) The floral bract which subtends the flower is longer than the calyx tube or the calyx teeth and up to twice as long as the pedicels, which are shorter than the calyx tube.

The pods are sparsely covered with rather long, simple hairs. Many of these characters fluctuate more or less, but the conditions described above are typical.

PERUVIAN ALFALFA CONSTITUTES A NEW BOTANICAL VARIETY OF MEDICAGO SATIVA.

In view of the numerous divergences which this strain presents, it is advisable that it be given a distinct varietal name. On the field the most easily recognized difference is the gray color of the plants previously mentioned, and this is best described by the term canescent. However, the Latin equivalent, *canescens*, has already been used for a variety of *M. orbicularis;* hence, the nearest Greek equivalent has been selected, and it is proposed to call the Peruvian alfalfa var. *polia.*[a] The type specimen, a portion of which is shown on Plate III, under No. 590159, and additional type material under Nos. 590160, 590161, 590162, and 590163, have been deposited in the National Herbarium. The following description is submitted:

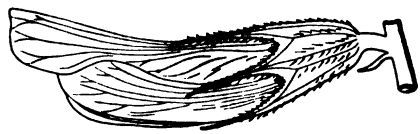

FIG. 9.—Flower of common alfalfa, showing calyx teeth as short as calyx tube. (Enlarged six times.)

Medicago sativa L. var. **polia,** n. var.

Plants large, vigorous, pubescent throughout; stems erect with few branches, woody at the base. Leaflets of lower part of plant small, linear lanceolate; the upper leaflets large, rather long obovate, with cuneate bases; 3–4 times as long as broad; generally longer than petioles. Veins of the leaves white. Epidermal cell walls of the upper leaf face locally thickened. (See fig. 12.) Petiolules long in comparison to petioles, usually about one-third to one-fifth the length of the latter. Stipules large, ovate-lanceolate, generally without teeth on the inner margin, at the top of the plant often as long or longer than the petioles. Racemes 6–18 flowered, rather short, loose and not capitate. Flowers rather large, attaining a length of 12 mm. Pedicels from half the length to as long as the tube of calyx. Calyx thickly covered with appressed, not glandular, hairs; the teeth as long as the tube and up to 1½ times longer. Corolla plum purple, standard rather broad. Wings somewhat exceeding the keel in length. Legumes from 4 to 6 mm. in diameter; twisted spirally from 2 to 4 times; the spirals not compressed; covered with long hairs; the dorsal and ventral sutures thickened and prominent, the central aperture small but clearly defined.

FIG. 10.—Flower of Peruvian alfalfa, showing calyx teeth longer than calyx tube. (Enlarged six times.)

The spirals of most alfalfas are almost flat, while those of the Peruvian variety are not compressed and in fresh specimens have an

[a] Πολιός, with gray or white hairs, hoary.

inflated appearance. The small mature head in figure 11 shows this character. Few heads were mature; hence, the early one shown here is much smaller than the average.

FIG. 11.—Small mature head of Peruvian alfalfa, showing expanded spiral pods. (Enlarged 1½ times.)

The presence of local thickenings of the cell walls of the epidermis of the upper face of the leaves was detected by Dr. Theo. Holm. These thickenings, magnified 240 times, are shown in figure 12. They have been found to be present in some specimens of ordinary alfalfa, but are very sparse. Their presence has considerable value as a diagnostic character, although they can be seen only by using the microscope.

PERUVIAN ALFALFA SEEDS ABUNDANTLY.

Ability to set seed freely is of the greatest importance in bringing a new variety into successful culture. This is especially true in the case of alfalfas, clovers, and other leguminous forage plants. Peruvian alfalfa has this good quality in a marked degree. In many localities alfalfa blooms profusely, but the flowers blast and fall off without forming seed. Several causes are responsible for this, but the most important ones are insect injury and the prevalence of unsuitable weather during that part of the flowering period when pollination takes place most readily. Under the climatic conditions to which the Peruvian variety has shown itself best adapted the flowers are easily fertilized and produce an abundance of seed. Observations thus far recorded tend to show that this form seeds more freely in cool weather than in hot. This indicates that the optimum temperature for seed

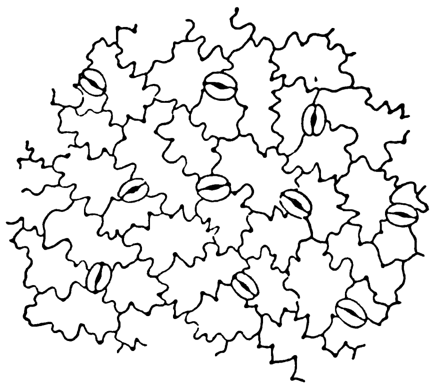

FIG. 12.—Local thickenings of the walls of the epidermal cells of Peruvian alfalfa leaves. (Magnified 240 times.)

production is considerably lower than the optimum for growth and that in both cases temperature is the limiting life history factor[a] controlling the functions in question.

The low optimum temperature for seed production may at first sight appear to work against the success of this alfalfa in the hot climate of the Southwest. This, however, is not proving to be the case, as the low zero point of growth makes possible the formation of seed in autumn when the temperature curves (see fig. 2) are falling. While definite data are as yet lacking on this point, it appears that an important practical advantage may result from the low optimum, as a later crop can then be devoted to seed production. This would result in an extra hay crop in years when seed is grown. Furthermore, farm work and other considerations make autumn the most convenient time for harvesting.

SOURCE OF PERUVIAN SEED.

The exact source in Peru of the seed used in these experiments (S. P. I. No. 9303) is not known. It was sent to the Department of Agriculture by Mr. Adolfo Eastman y Cox, who in his letter transmitting the same said:

> The seed sent is of the Peruvian variety, and I hope it is a true sample, as I asked the agents to spare no pains in getting seed of the best quality. I send it as a present to the Department of Agriculture, to whose liberality in sending me various of its publications I am deeply indebted.
>
> In the Experiment Station Record, trials on the value of different varieties of alfalfa are mentioned, but nowhere is the Peruvian variety spoken of. As far as my experience goes, the last has over the Chilean variety the following advantages: The stems are hollow and more succulent and grow higher. It commences its growth earlier in spring and grows till later in autumn. Owing to this advantage the crop per acre is heavier. On the other hand, care has to be taken in feeding cattle on it, as it is apt to produce hoven (bloating).
>
> I should be pleased if the results obtained with it would correspond with my desire that it may be of some use to American agriculturists.

It is probable that the tendency to cause bloating mentioned by Mr. Cox may be due to the hairiness of the plants, as is the case in red clover. It has been found that in thick stands the plants have very few hairs except at the top. Thick seeding, not less than 20 to 25 pounds to the acre of good germinable seed, is therefore recommended. In addition, this overcomes the tendency of the plants to

[a] The theory of limiting factors has been recently discussed by several investigators. Perhaps the most notable papers that have appeared are those of Blackman and Smith, as follows: Blackman, F. F.: Optima and Limiting Factors, in Ann. Bot., 19: 281–295, April, 1905. Smith, A. M.: On the Application of the Theory of Limiting Factors to Measurements and Observations of Growth in Ceylon, in Ann. Roy. Bot. Gardens, Paradeniya, 3: 303–375, November, 1906.

become hard and woody, leaving the stems even more succulent than those of the common alfalfa at the same stage of growth.

It is not known that the divergences which have been described as separating this variety from our commonly cultivated form hold good for all seed of Peruvian origin. Indeed, there is every reason to believe that they do not; but it does seem reasonable to suppose that the parent seed of the lot used in these experiments may have been grown for many generations at a high altitude in an equatorial region where the annual range of temperature is comparatively small—the summers are not very hot nor the winters very cold. There are well-authenticated reports of alfalfa growing in the Andes up to an altitude of 3,426 meters, or, roughly speaking, 11,000 feet. In this connection, a further illustration has been found of the practical importance of the zero point in plant economy.

ALFALFA PROPAGATED BY CUTTINGS.

André,[a] in a description of Ibarra (78° 17′ W.; 0° 24′ N.; alt. 7,530 feet) and its environs in northern Ecuador, thus describes a method of vegetative propagation[b] of alfalfa which he found in use in this region:

> In examining the methods of cultivation, I found that lucern—the alfalfa so valuable for stock—is not sown but planted by hand. In order to seed down a field it is first plowed deeply, and the soil well loosened—which is easy in these sandy soils—then pieces of the roots of lucern are planted 50 to 60 centimeters (20 to 24 inches) apart. A crop the same year is assured, whereas two years' delay results if seed is used. It is now June, the time when this planting is done. The farming population is also harvesting the peas, beans, and wheat.

[a] André, Ed. L'Amérique équinoxiale, etc., in Tour du Monde, vol. 45, No. 1171, 1883, first half year, p. 374.

[b] Westgate and Oliver, in a recent bulletin (The Application of Vegetative Propagation to Leguminous Forage Plants, Bul. No. 102, Part IV, Bureau of Plant Industry, 1907), describe a method of propagating alfalfa from cuttings suggested by Dr. B. T. Galloway. Inability to secure sufficient quantities of seed has often delayed the bringing of newly introduced plants into commercial culture. Work in selection has also been greatly hindered by the length of time required for propagating seed enough for field trials. The method of propagation by cuttings described in the bulletin mentioned will be very useful in helping to overcome both of these difficulties. A few plants of the Peruvian alfalfa described in the present paper, which withstood the winter of 1903–4 in Washington, were used as the basis of their experiments. It was observed that in 1903 a plat of Peruvian alfalfa in the grass garden of the Department of Agriculture was not injured by the leaf-spot fungus (*Pseudopeziza medicaginis*), while a check plat of common alfalfa was almost destroyed. Although leaf-spot is not regarded as a particularly destructive disease in regions where alfalfa is grown under irrigation, it does considerable damage under the humid conditions prevailing in the eastern United States, where great interest is now taken in alfalfa culture.

André further states that he found the mean annual temperature, measured by the method of Boussingault, equal to 16° C. (60.8° F.).

It is apparent from this that the sum of the daily temperatures above the zero point during the growing season is sufficient to produce a crop during the same year if the method of propagation by cuttings is used, but when seed is used two years are required to reach a sufficient total sum of heat to produce a crop. In this case, however, the low zero point is a secondary factor, as the difference in the time required is not due wholly to ability to grow at relatively low temperatures. Another factor—the utilization of a reserve supply of plant food—is probably the most important influence in shortening the time necessary for producing a hay crop.

That the practice of propagation by cuttings is still used with great success in the Ecuadorian plateau is shown by a recent report on alfalfa culture by Consul-General Herman R. Dietrich, of Guayaquil, based on information furnished by Señor Luis Martinez, formerly chief of the section of agriculture of the Department of Public Instruction of Ecuador. The paragraphs in question are as follows:

Cultivation.—Sometimes the seed is sown broadcast in the field, but the most usual manner is to transplant the shoots in lines or furrows, to facilitate irrigation. After each crop is cut the soil at the roots of the plant is loosened and the field is irrigated.

Yield.—In rich soil the yield is enormous, sometimes reaching 120,000 pounds per hectare per year. The normal yield is 80,000 pounds. In the table-lands the alfalfa gives from five to seven crops yearly. In the very high altitudes, of 2,800 meters or more, it scarcely gives three crops per year.

As there is no winter in Ecuador the alfalfa is always fresh and vigorous, and for that reason it is not made into hay.

THE GUARANDA ALFALFA OF ECUADOR.

The famous "Guaranda" alfalfa, so called because extensively grown around Guaranda, the capital of the province of Bolivar, at an altitude of about 8,894 feet, proves to be very like the Peruvian alfalfa already described. The Guaranda alfalfa sent to the Department of Agriculture by Señor Martinez (S. P. I. 14972) shows the same upright habit of growth as the Peruvian alfalfa, the same or a very similar zero point for growth, and the same large plum-colored flowers and long calyx teeth. Although much more hairy than ordinary alfalfa, it is not so hairy as the Peruvian, and the petiolules are slightly shorter in proportion to the petiole. Aside from these two points last mentioned the Guaranda alfalfa seems to be the same as the Peruvian, and more complete material will probably prove it to belong to the variety *polia*, which doubtless extends to all the high table-lands along the Andes where alfalfa culture is practiced.

The well-known botanist Luis Sodiro, S. J., writes concerning alfalfa culture in the higher Andean plateau as follows:[a]

. . . The "Velasco" property, belonging to Señor J. Julio Barba, near the town of Pomasqui, three leagues from Quito, . . . is situated at an elevation of 2,800 meters (9,186 feet): the mean temperature is between 15° and 16° C. (59°–60.8° F.), with slight variations between the day and the night; the soil is sandy and sufficiently provided with organic matter; the surface is almost horizontal; the irrigation, though not abundant in proportion to the extent of the tract cultivated, is amply sufficient for the needs of vegetation. . . .

I visited this property during the latter part of August of the present year, and in spite of the five months' drought that had just passed, interrupted only by a few light showers of rain, I found the whole field in the best state of growth that could be desired. The turf in flower, then near the time of the harvest, measured from 80 to 100 centimeters (31 to 39 inches) in spite of being only 50 days old.

Ordinarily cuttings are made every sixty days. Each square, consequently, may be cut as many as six times annually.

The variety that is cultivated there is what is called the "Guaranda," from the town of this name in the province of Bolivar.

The preparation of the land for planting depends on its condition and requires its division into sections, the making of the proper canals for irrigation, cleaning it from weeds, etc. In sowing the seed it is usual to employ from 20 to 25 pounds per hectare (17¾–22¼ pounds per acre). Four or five months after the sowing it is in condition to be cut for the first time,[b] after which it does not require more than from fifty to sixty days, according to the local conditions, between one cutting and another, to be newly harvested.

The value of the annual product of a hectare can be considered as from $12.50 to $15, and the cost of production from $3 to $4. A field well cared for will remain in good condition for thirty years; but these figures will also vary greatly according to the condition of the soil, so that it is difficult to formulate general data.

At Phoenix, Ariz., Guaranda alfalfa sown with eleven other sorts early in November, 1906, was reported on February 23, 1907, as having an "excellent stand" and being the "best looking alfalfa on the plats," despite the late date of seeding.

ADVANTAGES AND DISADVANTAGES OF PERUVIAN ALFALFA.

It is just as important to know the weaknesses of a variety as its points of strength.

The present investigations have demonstrated that in the area to which it is suited Peruvian alfalfa has numerous advantages over all other sorts. It has greater vigor, grows more rapidly, and recovers

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[a] This important letter, dated Quito, September 28, 1907, is addressed to Consul-General Herman R. Dietrich, at Guayaquil, whose kindness in sending this and other valuable information on Andean alfalfa culture is here gratefully acknowledged.

[b] To judge from André's statements (p. 26), it is highly probable that such alfalfa fields must have been planted with cuttings, as seedling alfalfa could scarcely reach a sufficient height for cutting in four or five months if grown at an altitude of 9,000 feet or thereabouts.

more quickly after cutting. By reason of its low zero point of growth it has a longer growing season, under favorable conditions continuing growth throughout the winter. It is more resistant to frost and matures its seed later in the autumn. These factors result in the production of one or two additional hay crops each year.

When grown in the region to which it is suited but two disadvantages have been noted—hairiness and a tendency to become woody. It has been found that both of these adverse conditions can largely be prevented by thick seeding. Lack of hardiness will always confine the Peruvian variety to limited areas. On account of the tendency of the stems to become hard and woody, it is not suitable for cultivation in regions where dry farming is practiced, for in order to secure the best results in the dry-land culture of alfalfa thin seeding is a necessity.

SUMMARY.

In the course of life history studies of alfalfa it has been found that a Peruvian strain, seed of which was presented to the Department of Agriculture by Mr. Adolfo Eastman y Cox, of Chile, is sufficiently different from all other alfalfas to constitute a distinct botanical variety. In addition to many technical differences, this new variety grows more rapidly, makes quicker recovery after cutting, begins growth earlier in spring, and continues growth later in autumn than the strains commonly cultivated. This results in one or two additional cuttings each year, thereby greatly increasing the yield to the acre. Besides this, the yield for each cutting is greater on account of the vigorous growth of the plants.

These differences, so important from an economic standpoint, have been explained in large part through the determination of the zero point of growth of this variety. The zero point of any crop plant may be briefly defined as the mean temperature above which growth begins in spring and below which it ceases in autumn. Peruvian alfalfa has an unusually low zero point, which enables it to take advantage of temperatures too low to stimulate growth in other kinds.

The view that cultivated alfalfa (*Medicago sativa* L.) is not one homogeneous species, but is composed of numerous strains, varieties, or even subspecies, appears to be substantiated by the present investigations.

The name *Medicago sativa* var. *polia* is proposed for the new variety, of which a technical description is given, together with a discussion of the probable conditions under which it originated.

Investigation has shown that Peruvian alfalfa can be grown to greatest advantage only under irrigation and in the Southwest, where the climate is mild in winter. It winterkills easily and hence should

not be grown where the winters are rigorous. It is not known to be drought resistant, and even if it should prove to be it has the drawback of becoming very woody if sown thinly, as is necessary when dry-land alfalfa culture is practiced. The chief causes of success in the area to which this alfalfa is suited and the main reason for failure in the region to which it is unsuited have been found to depend on the same factor, namely, the low zero point of growth. In the one case this makes growth possible during an unusually long season, resulting in greatly increased yields; while in the other it is responsible for the presence of tender tissue when cold weather comes, which results in the killing of the plants by the first severe freeze.

It is hoped that the observations here recorded will indicate lines on which the breeding and selection of alfalfa and other crops may be conducted, based on a knowledge of the life-history factors controlling the growth of the plant.

The Department of Agriculture has very little seed of this variety on hand at the present time, and none for general distribution. During the current season it is hoped that a small supply for propagating purposes will be secured from the experiments now under way. Cooperators who have been furnished with seed should devote their plats to seed production, in order to aid in the extension of this promising alfalfa in the area to which it is particularly suited—the Southwest.

PLATES.

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DESCRIPTION OF PLATES.

PLATE I. (*Frontispiece.*) A single plant of Peruvian alfalfa, showing its habit of growth, lack of branching, etc. It is 3 feet from the ground to the arrow near the top. The plant is one year old and was grown at Yuma, Ariz. Two stems from the plant here shown have been deposited in the National Herbarium under No. 590160 as paratypes. (Negative by Mr. C. S. Scofield.)

PLATE II. Fig. 1.—A plat of Peruvian alfalfa on the United States Reclamation Service tract, Yuma, Ariz. Average height of plants fully 3 feet. Photographed June 6, 1907. Fig. 2.—Kebilli Oasis alfalfa growing on a plat contiguous to that of the Peruvian variety shown in figure 1. Although these plats are of the same age and have received the same cultural treatment, the Oasis alfalfa is not yet knee high, while the Peruvian is nearly waist high. Photographed June 6, 1907.

PLATE III. A specimen of Peruvian alfalfa, photographed June 6, 1907, at natural size, from fresh material grown at Yuma, Ariz., showing flowers and almost mature head. This branch and the stem from which it was taken have been deposited in the National Herbarium under No. 590159 and constitute the type of *Medicago sativa* var. *polia.*

FIG. 1.—A PLAT OF PERUVIAN ALFALFA ON THE UNITED STATES RECLAMATION SERVICE TRACT, YUMA, ARIZ.

FIG. 2.—A PLAT OF KEBILLI OASIS ALFALFA GROWING ON A PLAT CONTIGUOUS TO THAT OF THE PERUVIAN VARIETY SHOWN IN FIGURE 1.

A SPECIMEN OF PERUVIAN ALFALFA, SHOWING FLOWERS AND ALMOST MATURE HEAD.

(Natural size.)

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 119.

B. T. GALLOWAY, *Chief of Bureau.*

THE MULBERRY AND OTHER SILKWORM FOOD PLANTS.

BY

GEORGE W. OLIVER,

Plant Propagator, Bureau of Plant Industry.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., October 7, 1907.

Sir: I have the honor to transmit herewith a manuscript entitled "The Mulberry and Other Silkworm Food Plants," by Mr. George W. Oliver, Plant Propagator of this Bureau, and recommend that it be published as Bulletin No. 119 of the Bureau series.

In 1903 Bulletin No. 34 of the series of the Bureau of Plant Industry, entitled "Silkworm Food Plants: Cultivation and Propagation," by Mr. Oliver, was prepared and issued at the request of Dr. L. O. Howard, Entomologist of the Department of Agriculture, who has charge of the investigations connected with silk culture in this country. Bulletin No. 34 has long been out of print so far as the supply of the Department of Agriculture is concerned. A new edition being called for, it was found that the electrotype plates of the publication mentioned had been destroyed, and it was therefore thought best to arrange with Mr. Oliver to prepare a new paper, bringing the information on this subject up to date. This purpose has been carried out in the manuscript now submitted.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE MULBERRY AND OTHER SILKWORM FOOD PLANTS.

INTRODUCTION.

The small group of trees belonging to the family Moraceæ includes those which supply the silkworm with food. There are three genera in the group: Morus, the mulberry (Pls. I to VI); Toxylon, the Osage orange (Pl. VII, fig. 1), and Broussonetia, the paper mulberry (Pl. VII, fig. 2). The last named is not true mulberry, although often mistaken for such and in some States miscalled the "white mulberry" on account of the white under surface of the leaf. It is absolutely worthless as a silkworm food plant.

The Osage orange provides excellent silkworm food only when matured leaves are used. Young succulent leaves when fed to the worms cause disease. Silk from the Osage leaves is of a very fine quality, but the young branches of this tree are thorny; this, together with the manner in which the leaves wither and pack down after gathering, makes them inferior to those of the mulberry. The young mulberry buds can be fed to the worms in the spring at a time when the Osage orange buds have not even commenced to swell.

The mulberries proper consist of several species, and of these there are numerous varieties. The white mulberry (*Morus alba*), shown in Plates I, II, and III, is most prized for feeding the silkworm; it is too tender, however, in northern latitudes with severe winters. The Russian mulberry (Pl. IV), which is a variety of the white mulberry (*M. alba* var. *tatarica*), is better adapted to cold regions. Although the leaves are smaller than in those of the white mulberry and much divided, entailing more work in feeding the worms, it is, nevertheless, considered an excellent food for silkworms. The Chinese *multicaulis*, another variety of the white mulberry, much favored for feeding purposes, is too tender in northern latitudes. Other varieties of *Morus alba* more or less used are Moretti, Downing, Rosea, and Japonica. The venosa variety of the white mulberry (Pl. VI) is used only as an ornamental plant and has no value for feeding silkworms.

The other two species commonly grown in the United States are the black and the red mulberry. The black (*Morus nigra*) is sometimes

used for feeding, but takes lower rank in this respect than *Morus alba* and its varieties. The red mulberry (*M. rubra*), the only species native to the eastern United States, is considered the most undesirable of all the mulberries as a silkworm food plant.[a]

PROPAGATION OF THE MULBERRY.

It is intended to show in these pages how the mulberry may be propagated and grown so as to provide the maximum quantity of leaves for the supply of silkworms. The white mulberry under good cultivation is a low-growing tree, seldom attaining a greater height than 25 or 30 feet. It will reach this height in a comparatively few years after planting. Although it will live to a good old age, its growth, like that of most other trees, is most rapid when young. As the trees attain their full height they become stocky and make a multitude of small growths, from which flowers and fruit are produced. The fruit, which is usually abundant, is not a favorite in this country, being generally considered too sweet and insipid. In shape it may be said to resemble more or less that of an elongated blackberry. In the vicinity of Washington, D. C., the trees flower about the middle of May and ripen their fruit in June.

METHODS OF REPRODUCTION.

The usual methods of propagating in use for fruit trees are employed, with varying degrees of success, in the case of the mulberry. These methods consist of budding, grafting, and layering, and the use of cuttings and seeds. Grafting and budding are by far the most expensive methods, and it is doubtful whether the results justify their use so far as raising mulberry trees is concerned. Part of the work connected with budding and grafting consists in raising stocks, which are seldom large enough for use until they are two years old. At this age the buds or grafts are inserted, and then troubles previously undreamed of present themselves to the inexperienced cultivator. Were the mulberry tree as easily managed so far as budding or grafting is concerned as are the peach and the apple, the use of these methods would be feasible; but unfortunately the mulberry is far from being an easy subject in this respect, and a few failures are apt to produce disappointment and disgust. It will frequently happen that old trees must either be removed or desirable varieties worked on them. Budding or grafting may be resorted to in such cases.

Raising young trees from cuttings of the 1-year-old ripened wood is a method which requires but little skill. As with budding and grafting, this method is instrumental in perpetuating varieties,

[a] The species known as *Morus celtidifolia* is native in the southwestern portion of this country.

as every rooted cutting will eventually be a reproduction of the tree from which it was taken. This is not the case with plants raised from seed, which always vary considerably from the parent. For this reason some mulberry growers in Europe object to the seed method. Some of the seedlings, even from a single parent tree, will vary greatly in the value of the leaves for feeding purposes. Some will be thin in texture and lacking in the necessary chemical constituents; some very hairy, while others will be thick, smooth, and in every way desirable. Experienced mulberry growers, however, can readily tell the value of a seedling tree for feeding purposes, and it is therefore possible to make a selection in this respect without much loss.

LAYERING.

Layering may be practiced when facilities for the other methods are not at hand and when a large number of plants is not required. It consists of bending down branches of low-growing trees or suckers from the base of the trunk, cutting half way into the wood, then making a cut of about an inch upward. This cut part of the shoot is buried in the soil to the depth of 6 inches, the soil well firmed about it, and a good-sized stone put on top. If kept moist, roots will soon form. The operation of layering may be performed at any time during the spring or early summer. Those shoots which have rooted may be separated from the parent and planted at any time during the autumn or early spring. When planting the rooted layer the top of the shoot should be removed; this will induce a strong growth the following summer.

SUMMER CUTTINGS.

Among seedling trees there will always be found individuals the leaves of which possess great adaptability for feeding purposes, such as suitable size and thickness and a less hairy surface than that ordinarily found. These should certainly be propagated to perpetuate those desirable characteristics.

Propagation should be started after the seedlings have made considerable growth, in order to insure a good supply of wood, and these plants should be increased by cuttings during the summer months. At this season it is advisable to retain some of the leaves on the cuttings and give treatment which will prevent shriveling during the process of rooting. The cuttings should be made from wood as ripe as possible. The leaves, besides being well matured, should be healthy and free from noxious insects. During July the lower parts of the current season's shoots will be found in good condition for propagating.

Trim the cuttings similarly to those shown in Plate V. At least two leaves shortened to one-half of their length should be allowed to

remain on the cutting. When placed in the propagating bed the slips should be inserted in the sand in a direction sloping from the operator. Good results will follow if a cool propagating house is used, with clean sand as the rooting medium. When a propagating house is not available a wide frame provided with sash will answer the purpose. The frame should face north, and if in the shade of trees so much the better. The sash should be kept shaded during sunshine, so that a humid atmosphere may be maintained until the cuttings take root. After they have made a considerable quantity of roots in the sand they should be transferred to beds in the open. These beds should be 5 feet wide. Place the rooted cuttings about 6 inches apart each way and water copiously until established, when they must be exposed freely to air and sunshine.

HARD-WOOD CUTTINGS.

The principal supply of plants may be secured by propagating from cuttings, which should be made from dormant wood taken from the trees just after the leaves have fallen. In no case should the cutting wood be less in diameter than a quarter of an inch. The cuttings should be about 10 inches in length, making the upper cut about one-half inch above a bud. The position of the lower cut is immaterial. The cuttings should now be tied in bundles of 50 and either stored for the winter or immediately put out where they are to root. Where the winters are not too severe, or in the Eastern States south of the twenty-ninth parallel, they should be put in the ground during the autumn. North of this it will be found best to keep them under cover until the ground is in a condition to be worked in the early spring. If they are kept even for a short time in a dry place they will lose their sap and become shriveled; therefore, they should be buried in moderately moist sand or sand and ashes. Under such conditions a good callus will have formed around the lower cut surface before the time arrives when they are to be placed in the open ground.

If sphagnum moss can be easily procured, it may be used very successfully as a substitute for sand or ashes, but in this case the bundles of cuttings should be smaller and they should be placed with the buds pointing upward, the moss to be packed tightly around them, with the top part uncovered. This is an excellent medium for inducing the formation of a good callus.

Previous to putting the cuttings in the open the soil should be plowed deeply, then harrowed and rolled until well pulverized. A furrow is made with a spade to a sufficient depth, a little sand thrown in the bottom, and in this the lower ends of the cuttings are placed. Fill in the soil to half the depth of the furrow, firm well with the

feet, and then fill in the remainder of the soil, leaving only enough of the cutting exposed to view to keep the top bud from being covered. Where there is danger of hard freezing weather after fall planting, cover the surface with rough stable litter, this covering to be removed before the buds begin to swell during the latter part of March.

The rows of cuttings can be arranged in beds of any convenient width, leaving spaces between the beds which will facilitate covering, watering, hand weeding, and cultivating. During the summer the plants should be gone over several times and all superfluous shoots removed, leaving only one shoot to each plant. If large enough, the rooted cuttings should be removed to nursery rows the following fall. In no case should the plants be removed from the cutting beds to permanent locations. If the plants make sufficient growth the first season, they should be severely cut back; otherwise, the operation should be deferred until the following season.

The length of stem to remain as the future trunk must be regulated according to whether a dwarf or tall specimen is wanted. It must be taken into consideration that the leaves are much more easily gathered from dwarf trees than from tall ones; in fact, they are more easily managed not only so far as leaf gathering is concerned, but also in pruning and in keeping noxious insects and fungous diseases under control. The leaves on a tall tree are not all developed alike; those on the side fully exposed to the sun will naturally be in a perfect condition, while on the opposite side they are softer and probably not so well adapted to the purpose for which they are intended. Medium-sized trees are therefore preferable for all purposes.

INDOOR SPRING CUTTINGS.

Another method of propagation from cuttings, and a very successful one, consists in selecting medium-sized shoots about the beginning of November. These, before being made into cuttings, are sorted into bundles of different lengths, tied, and heeled in ashes or sand, or in a mixture of both, and protected by a frame having a northern exposure. During the winter they are taken out and cut into lengths of about 5 inches. These are tied in bundles and buried in moist sand or moss. In early spring they are untied and inserted quite thickly in the sand of a propagating bed having a mild bottom heat, where they will root rapidly. When such a bed is lacking, wooden flats about 4 inches deep may be used for the reception of the cuttings, but they must have the protection of a frame with slight bottom heat and be covered with sash. If a little loamy soil is placed in the bottom of the flats and the remaining space filled with sand, the cuttings will remain in good condition for a considerable time after

rooting and until a favorable opportunity arrives for planting them out in nursery rows. If those rooted indoors are given plenty of air after being rooted in the bed they can be transferred during dull weather.

PROPAGATION BY SEEDS.

Propagation by seeds is an exceedingly simple operation, and if ordinary care is given successful results will follow. Seeds sown shortly after being harvested will germinate in a few days. If kept over winter and sown in early spring the seedlings should appear in fourteen days. When the seed is spring sown, the seedlings will, if the weather be propitious, attain a height of from 12 to 18 inches in one year, but during dry seasons they will only grow from 6 to 12 inches. Seedlings from seeds sown immediately after the fruit ripens are always small at the end of the season, but they produce strong plants the season following.

The mulberry, like the strawberry, blackberry, and raspberry, does not ripen all of its fruit at one time; consequently several gatherings are necessary before a crop is harvested from any one tree. The earliest fruits can be harvested immediately after they are ripe, and the seed sown if desired. It should be remembered that seedlings thus raised have comparatively little time to make their growth; therefore, every day counts.

In gathering the fruit it will be found easiest to shake the tree and pick the fruits from the ground. To remove the seeds from the surrounding pulp, put the fruit into a large bucket or tub and squeeze with the hands until it becomes a jelly-like mass. Add water and stir well until the contents are thinned sufficiently to allow the seeds to sink to the bottom. The remaining material can be poured off. The seeds should be exposed to the air until dry. If it is desired to sprout them the same summer, they should be sown in beds in the open, the soil having been previously well worked by deep plowing and gone over several times with a harrow and roller. When the soil is sufficiently pulverized, the ground should be marked off into beds 5 feet wide and of any convenient length, leaving a space of 2 feet between the beds. To prevent washing of the soil and also to minimize the evil effects of drying winds, drive some stout stakes into the ground along the sides and ends of the beds, and to these nail 8-inch or 12-inch boards. The surface of the bed should be leveled and all stones and roots of plants removed with a hand rake.

Sow the seeds broadcast, taking care not to sow them too thick, as there is danger of the seedlings crowding each other. Crowding produces weak plants, because even the best soil is capable of supporting only a certain number of plants to the square foot. Press

the seeds into the soil with the back part of a spade and cover lightly with soil screened through a quarter-inch sieve.

In order to obtain the best results, the seed beds should not be exposed to the sun until a considerable time has elapsed after germination. This condition may be provided as follows: Procure some pieces of 2 by 3 inch scantling. Place two of the pieces parallel to each other 5½ feet apart. Nail laths from one to the other, using the 2-inch surface in which to drive the nails. Leave a 1-inch space between the laths. The slats are put lengthwise over the beds and can be used with or without the side boards. Over the slats spread archangel mats, or canvas, until germination takes place. These coverings should be frequently dampened. After the seedlings show above the ground the cloth coverings are to be kept on during the hottest part of the day only, and when the first true leaf appears they may be removed altogether and the shade necessary thereafter supplied by the lath slats. Water must be supplied if the soil needs it. With spring-sown seed the coverings over the lath slats may be dispensed with, but the surface of the bed should not be allowed to become dry until the seedlings are large enough to take care of themselves.

To raise seedlings of the Osage orange, gather the fruits as they fall from the trees and leave them out of doors until they rot. The seeds are then easily removed. Keep them in damp sand during the winter and sow in the spring, covering them 1 inch with fine soil; transplant the seedlings during the following spring.

GRAFTING AND BUDDING.

In the silk-raising countries of Europe it is claimed that the leaves of trees raised from cuttings and seeds are superior for silk production, but that the quantity of leaves produced by trees so propagated is only about one-half the bulk of those from grafted or budded trees. Therefore, to produce a large quantity, grafting and budding methods of propagation are practiced to a great extent. This is an important point to consider, and the writer is inclined to the belief that in the propagation of plants giving the highest grades of silk there will be little danger of a scarcity of material, as in most parts of the United States the mulberry thrives as well as, if not better than, anywhere in Europe.

For those who decide to try propagating by grafting and budding two of the most successful methods of performing the operation are here described.

ROOT GRAFTING.

Root grafting is done in February and March. The stocks, which are one or two year old seedlings of the Russian mulberry (*Morus*

alba var. *tatarica*), should show a diameter of at least three-eighths of an inch to give a satisfactory union. The stocks should be lifted in the fall and "heeled in" out of the reach of frost. The scions should be cut while in a dormant state and buried in damp sand in a protected place.

In the latter part of February the work of root grafting may be started. The preparatory work consists in securing a quantity of strong cotton and of grafting wax made of beeswax two parts, resin two parts, and mutton tallow one part. Put these ingredients in a small tin bucket, place on a hot stove, and when melted drop in one or more balls of the cotton, allowing them to remain in the melted wax for five minutes; remove with a pointed stick. When cool they are ready for use. Procure a deep box, in which the stocks are placed, keeping them covered with a dampened sack; another box should be provided for the scions, similarly protected, and a third one for the grafted roots. These precautions are necessary, as even a little exposure to dry air is always detrimental.

In beginning work with the stocks, sever the top from the root at the collar; this can be done best with a pair of pruning shears. The small lateral roots may be removed or shortened. Take a scion at least 5 inches long and attach by the tongue method. Select stocks and scions of as nearly the same diameter as possible and make a slanting cut at the bottom of the scion and a similar cut at the top of the stock. In the case of the scion, make an upward incision at a point about one-third of the length of the cut surface from the base; this will form a tongue. Next make a corresponding incision downward near the top of the slanting cut on the stock. The idea is to have the tongue of the scion take the place which the knife blade occupies when making the incision in the stock. When the two parts are fitted so that the bark of stock and of scion comes neatly together at one side, or at both if possible, bind firmly with the waxed cotton. This material should be used in preference to raffia, because when the grafted stock is buried in the ground raffia will be certain to rot before the union takes place, while cotton will remain in good condition for a long time.

After the fitting and tying have been done, the grafted stocks should be tied in bundles of 25, the first tie to be made rather firmly near the upper part of the scions; secure them again near the base of the scions, but not as firmly as before. Care must be taken so as not to displace the fitted parts. The bundles should now be buried in sand in a frame or other protected place until planting time arrives. The grafted stocks should be planted out just as soon as the condition of the soil will permit. Plant them so deep that only the top bud is exposed to the light.

The subsequent treatment is in all respects similar to that given for cuttings. Mark the kinds, with the dates of grafting and planting, on large labels which will not be easily displaced.

SCION OR SPRIG BUDDING.

Scion or sprig budding is perhaps the most successful and easiest to accomplish of all methods where it is desired to perpetuate an especially good tree. It is practiced on stocks which have not been transplanted for at least one year previous to the time when it is desired to bud. The stocks should be much larger than those used for root grafting. The most desirable time for the operation is in the spring, when the bark lifts easily; this will necessarily be after the stocks come into leaf. The scions must be selected from shoots of the previous season's growth, short and stocky, with two buds present. They should be cut from the parent plants in the fall and kept dormant until the opportune moment arrives when the stock plants are in a receptive condition.

In preparing the stock for the scion the preliminary work is similar to that in shield budding the peach, cherry, or rose. At a point a little above the collar of the stock a transverse cut is made through the bark for a distance of half an inch or more around the stem. This is followed by a longitudinal cut, beginning in the middle of the first cut and extending downward for about an inch. Lift up the bark at each side of the long cut and it is ready for the scion, which is prepared for insertion by making an oblique cut through the base, so as to leave a cut surface about an inch long, and then tie the parts together so that they will be held firmly while the union is taking place. In order to exclude air and moisture, grafting wax or clay should be applied.

Within two weeks from the time of budding the union will be effected if everything has gone well. The ligature should not be removed, however, until there is danger of its cutting into the bark. The most essential part of the subsequent treatment consists in heading back the stock, so that the future head of the tree will be formed by the growth of the scion, and to do this successfully good judgment must be exercised. Cut off only a part at first, leaving some foliage on the stock until the buds on the scion begin to push, when that part of the stock above the union should be removed with a sharp knife. Cover with grafting wax the wound thus made.

SHIELD BUDDING.

The shield system of budding may be used, but only in the spring, as the mulberry does not take kindly to shield buds inserted during the season suitable for budding most of our fruit trees.

Shield budding consists in selecting a stock, either a branch or stem, from which the bark slips readily. In raising the bark of the stock for the reception of the bud, the work is similar to that described for scion or sprig budding. The bud is usually selected from dormant wood kept over winter in ashes or sand, but for this there exists no necessity, because there is always present an abundance of dormant buds on a growing plant, and these answer the purpose much better than buds from dormant wood. To remove them, make an incision in the stem with a sharp knife about five-eighths of an inch below the bud; bring the blade up under the bud, severing a section of bark one-quarter of an inch in width, with the bud in the center. Bring the blade out a little above the bud. If this operation is neatly performed, the bud will require no further trimming before being inserted under the bark. The bark of the stock is then firmly bound over that of the bud and the parts kept in position with raffia or soft string. No waxing is necessary. The union should take place within fifteen days, after which the ligature should be loosened or removed, as proves necessary.

RAISING STOCKS FOR GRAFTING AND BUDDING.

In grafting and budding from any particular variety which it is desired to perpetuate, the Russian mulberry (*Morus alba* var. *tatarica*) is the one used as stocks. It is of a robust-growing nature and has been found well adapted to the soils and climates of all the agricultural belts of the United States. It is this variety that is so much used in the West and Northwest for hedges, as it is the hardiest of all the mulberries.

Stocks are best raised from seeds, and a supply for this purpose should be obtained from a reliable source to avoid unnecessary delay and disappointment. The sowing and the subsequent management of the seedlings are the same with stocks as with seedlings for general planting, except that when planted in nursery rows they should be placed about a foot apart so as to give an abundance of space for the operator.

SOIL.

So far as has been ascertained, the mulberry is not particular as to the character of the soil in which it is planted. It seemingly grows equally well in a great variety of well-drained soils. Even in sandy and gravelly situations it holds its own. In shallow soils over hardpan the mulberry thrives after most of our fruit and ornamental trees have given up the struggle. Under the same conditions the Persian mulberry has been found to fruit abundantly.

Notwithstanding its behavior under what would be supposed adverse conditions, there are few plants which respond more vigor-

ously to applications of manure than the mulberry. In Japan it has recently been shown that by liming alone the percentage of fiber in the leaves decreased very perceptibly. Again, by liming and also manuring with sodium nitrate and calcium sulphate a still further reduction in the fiber was apparent. The trees operated on were 1½ meters (5 feet) high. Each tree was treated with 500 grams (1.1 pounds) of lime, 400 grams (0.9 pound) of sodium nitrate, and 200 grams (0.44 pound) of calcium sulphate. How the caterpillars fared as a result of this change in the composition of the leaves is not stated.

PLANTING.

The all-important operation of planting may be performed in either the fall or spring. When done in the autumn it should be attended to immediately after the leaves have fallen. In spring the trees may be transplanted at any time after the ground is in a workable condition and up to the period when the buds are about to burst into growth. Spaces intended to be planted should be deeply worked beforehand by plowing and harrowing, and after planting the weeds should be kept down.

The distance between the trees should not be less than 10 feet in the rows, and the rows should be the same distance apart. If the field devoted to the trees is more than 2 or 3 acres in extent, wider spaces should be left at intervals for wagons, etc. It is certain that trees planted 10 feet apart will eventually occupy all the space, but when there is danger of their becoming too much crowded, enough of the plants may be rooted out and burned to allow the remainder abundant space to develop. If this is done, those which are to remain permanently should be trained accordingly. The above arrangement is the best for trees, nearly all the branches of which can be reached from the ground, not only for pruning, but also for leaf gathering.

In planting trees similar precautions should be taken to those employed in the case of ordinary forest trees; that is, not to allow the roots to become in the least dry from the time they are lifted from the nursery rows until planted in the field. As soon as they are lifted the roots should be dipped in a mixture of soil and water and kept covered until planted, so that they will not become dry. If the ground is naturally hard and the soil is poor, dig large holes, even for very young trees, as they grow rapidly and should be encouraged to make good stout growths from the beginning. Put some good soil in the hole, spread out the roots on this, and cover with several inches of fine soil before firming with the feet. Allow the roots to be about the same depth in the hole as they were in the nursery rows. Prune

back the growth of young trees one-half in the fall, and, if necessary, cut back to strong buds in the early spring.

PRUNING.

The pruning of the trees presents no special difficulties so long as it is done early enough in the season to avoid late growth, which, if caught by cold weather before ripening, will die during the winter. The principal pruning should be done in winter and should consist of shortening back strong growths so as to form a low spreading tree. Keep the central part of the tree as free of growth as possible, to admit light and air.

After the first cutting back, select three or more of the strong shoots to form the principal branches. If they are strong and show a disposition to grow upright, they may be kept apart by using three sticks tied in the shape of a triangle; place these in the center of the tree and tie the branches to them until they grow in the desired direction. By careful attention to cutting out the undesirable growths the tree can be made to assume any desired shape.

In gathering leaves always allow at least one-half of the crop to remain on the tree to insure its perfect health. Single branches should never be entirely defoliated. If some of the trees show signs of failing vigor as a result of excessive leaf gathering, it is advisable to allow them to grow for a season without picking and by the early pruning out of unnecessary growth to permit those growths which are desirable to ripen.

FOOD FOR EARLY-HATCHED WORMS.

It sometimes happens that the eggs will hatch early in the spring before the mulberry leaves have unfolded. In such cases lettuce leaves (of the hard-leafed varieties) may be temporarily used. The oyster plant (*Tragopogon porrifolius*) may also be used for a few days. In addition to these substitutes, the mulberry leaf buds are sometimes scraped off, mashed to a fine pulp, and fed to the newly hatched worms. Where this latter course is adopted, the terminal twigs of the trees should be cut off and the buds on the pruned portions used.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. (Frontispiece.) Old trees of the white mulberry (*Morus alba*) in the grounds of the United States Department of Agriculture.

PLATE II. Branch of the white mulberry (*Morus alba*), with large undivided leaves of thick texture and smooth surface. The leaves of this variety are preeminently adapted for silkworm food.

PLATE III. Branch of the white mulberry (*Morus alba*), with divided leaves. Seedlings from the same parent will sometimes have leaves of the divided form, others assuming the undivided shape shown in Plate II, while some may have both forms on the same tree.

PLATE IV. Branch of a seedling Russian mulberry (*Morus alba*), variety *tatarica*. This mulberry, owing to its extreme hardiness, is used for stocks on which to graft or bud the most valuable varieties in order to perpetuate their characteristics, propagation from seed being altogether unreliable for perpetuating varieties.

PLATE V. Summer cuttings of the white mulberry (*Morus alba*), with leaves shortened to prevent excessive evaporation while rooting.

PLATE VI. Branch of the white mulberry (*Morus alba*), variety *venosa*. This is an ornamental variety and is of no value as food for silkworms.

PLATE VII. The Osage orange and the paper mulberry. Fig. 1.—Leaves, fruit, and bark of the Osage orange (*Toxylon pomiferum*). Fig. 2.—The paper mulberry (*Broussonetia papyrifera*). A, leaf from old tree; B, leaf from 2-year-old seedling; C, twig with female flowers. This variety is without value as food for silkworms.

BRANCH OF THE WHITE MULBERRY (MORUS ALBA), VARIETY VENOSA.

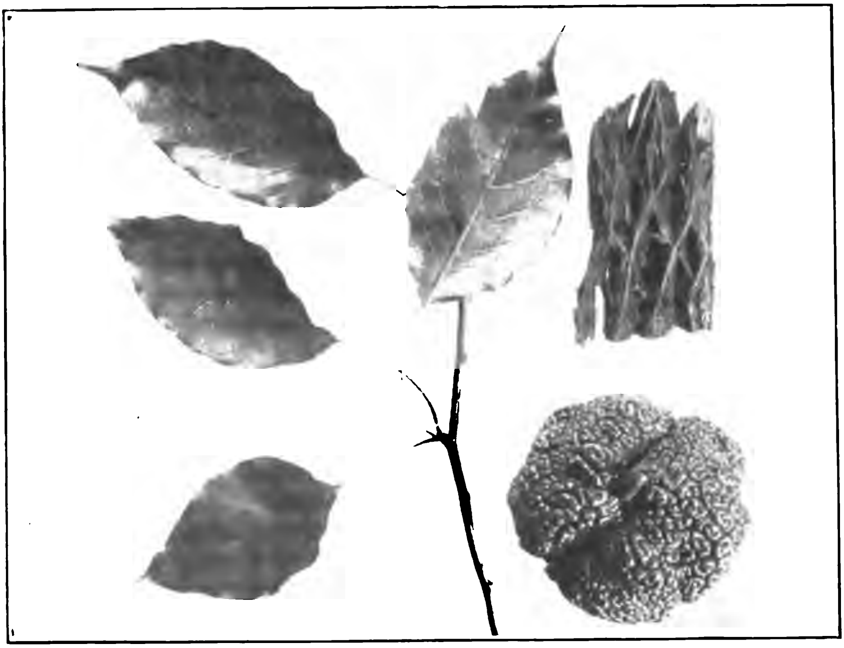

FIG. 1.—LEAVES, FRUIT, AND BARK OF THE OSAGE ORANGE (TOXYLON POMIFERUM).

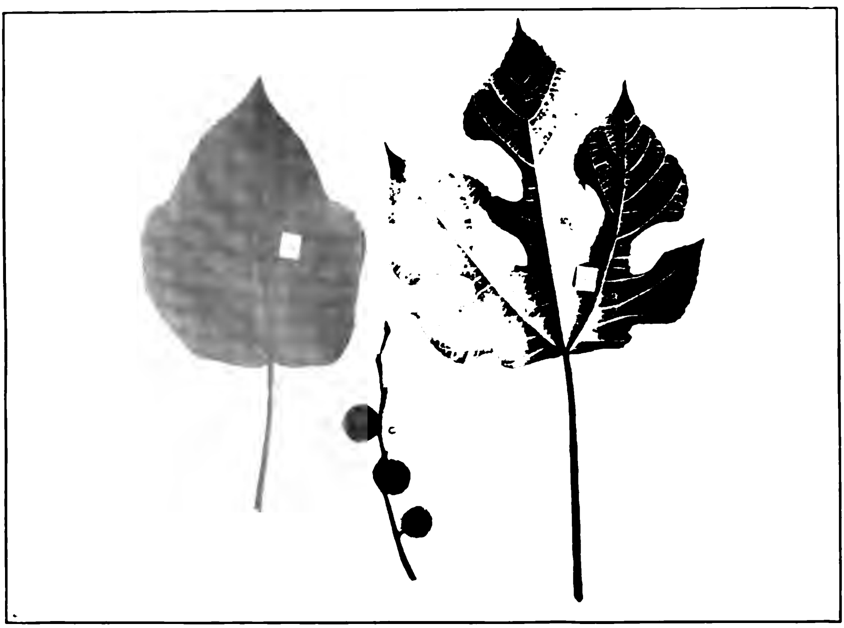

FIG. 2.—THE PAPER MULBERRY (BROUSSONETIA PAPYRIFERA).

A, Leaf from old tree; B, leaf from two-year-old seedling; C, twig with female flowers.

THE OSAGE ORANGE AND THE PAPER MULBERRY.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 120.

B. T. GALLOWAY, *Chief of Bureau.*

THE PRODUCTION OF EASTER LILY BULBS IN THE UNITED STATES.

BY

GEORGE W. OLIVER,

PLANT PROPAGATOR, BUREAU OF PLANT INDUSTRY.

ISSUED JANUARY 10, 1908.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., October 3, 1907.

Sir: I have the honor to transmit herewith a manuscript entitled "The Production of Easter Lily Bulbs in the United States," by Mr. George W. Oliver, Plant Propagator of this Bureau, and recommend that it be published as Bulletin No. 120 of the series of the Bureau of Plant Industry.

The Easter lily is of great importance to florists, its bulbs being largely imported from Bermuda and Japan. The imported bulbs, however, are not satisfactory, and if the industry of forcing these plants so that they will be in flower at Easter is to be continued it will be necessary to produce the bulbs in this country. The problem of producing these bulbs in the United States has been studied for some years by members of the staff of this Bureau, and the accompanying paper summarizes the information on the subject to date. Mr. Oliver has shown that healthy bulbs can be readily and profitably produced in this country and that disease-resistant strains can easily be maintained.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE PRODUCTION OF EASTER LILY BULBS IN THE UNITED STATES.

DISEASE IN IMPORTED BULBS.

At the present time Bermuda is the main source of supply of Easter lily bulbs for the United States. The mild winter climate of the island is very favorable to the growth of these lilies in the open air, but the area of arable land is limited and many of the farms are so small that alteration of crops is not practiced with lilies, onions, and potatoes, which are the staple crops.

As a result of these conditions and the fact that careful selection is not practiced the vigor of the lily bulbs produced is lessened and weak plants are produced from them. As a consequence the plants grown from Bermuda bulbs in greenhouses in the United States are in a very unsatisfactory condition. In many cases from 50 to 75 per cent of the plants are diseased to such an extent as to be practically unsalable; in fact, they are so seriously affected that many florists would willingly give up their cultivation altogether were it not that their patrons demand the lily in its season. The problem how and where to produce the bulbs within our own borders therefore confronts those who would continue in this industry. That this problem will be solved soon there is little doubt. It is not likely that American growers will be able to harvest the bulbs and place them on the market as early as the Bermuda crop, but judging from present appearances their efforts will result in supplying bulbs practically free from disease.

It is said that about 3,000,000 bulbs are annually imported from Bermuda and that about 20,000 salable bulbs, ranging in size from three to five inches in circumference, can be grown on an acre of ground from mother bulbs planted the preceding year. The second year's crop of bulbs of that size, whether from seedlings or from bulbs, should therefore bring from $1,000 to $2,000 an acre.

PREVIOUS EFFORTS TO ESTABLISH THE GROWING OF EASTER LILY BULBS IN THE UNITED STATES.

During the past decade many attempts have been made by seed firms and others, including the Division of Botany of the Department of Agriculture, to grow the Easter lily commercially in the Carolinas,

Florida, and other States. These efforts were useful in pointing out places where it was evidently impossible to produce bulbs cultivated after the manner now pursued in the Bermudas and Japan.

Both large and small imported bulbs were planted at various places and received the best of care, but in every case the crop when harvested did not warrant a continuation of the experiments. All of these failures resulted partly from unsuitable soils, but principally from unfavorable climatic conditions. It is reasonable to suppose that the lily disease so prevalent in imported bulbs played its part in making the experimental work a failure.

TRIALS OF IMPORTED BULBS IN CALIFORNIA.

The experimental work now being conducted on the Pacific coast promises successful results, but even in that region, favored as it is with nearly ideal conditions in the matter of soil and climate, good results can not be expected by following the old methods of asexual propagation practiced in the Bermudas. This has been shown repeatedly in connection with several large lots of selected imported bulbs planted out in widely different localities for seeding purposes. These plants show the usual amount of disease on the foliage, while the apparently healthy plants propagated by division and by scales also show the disease to such an extent that it seems a difficult matter to get rid of the trouble by purely vegetative methods of reproduction from selected bulbs.

ORIGIN OF THE EFFORT TO GROW SEEDLINGS.

A few years ago Dr. Albert F. Woods, of the Bureau of Plant Industry, in his investigations of the lily disease discovered that seedling plants were practically free from the disease. About the same time Mr. E. M. Byrnes, then connected with the Office of Public Buildings and Grounds, but now with the Bureau of Plant Industry, found that the progeny of crossed varieties were more vigorous than either parent.

At the instigation of Dr. B. T. Galloway the writer grew a large number of seedlings in the Department greenhouses, and from these several pounds of seed resulted. This was distributed on the Pacific coast and in Florida. The seedlings grown in California showed conclusively that with liberal treatment first-class bulbs can be grown by this method much more quickly than by asexual propagation. The plants are almost free from disease. A few plants show it here and there in first generation seedlings, but in the second and third generations it is difficult to find an affected plant. These results have been so encouraging to practical men on the coast that several are now engaged in getting up a stock of seedlings upon a large scale.

THE MOST SUITABLE LOCALITIES FOR LILY BULB GROWING.

Although enough has not been done in an experimental way to ascertain all of the localities where lilies can be grown successfully,

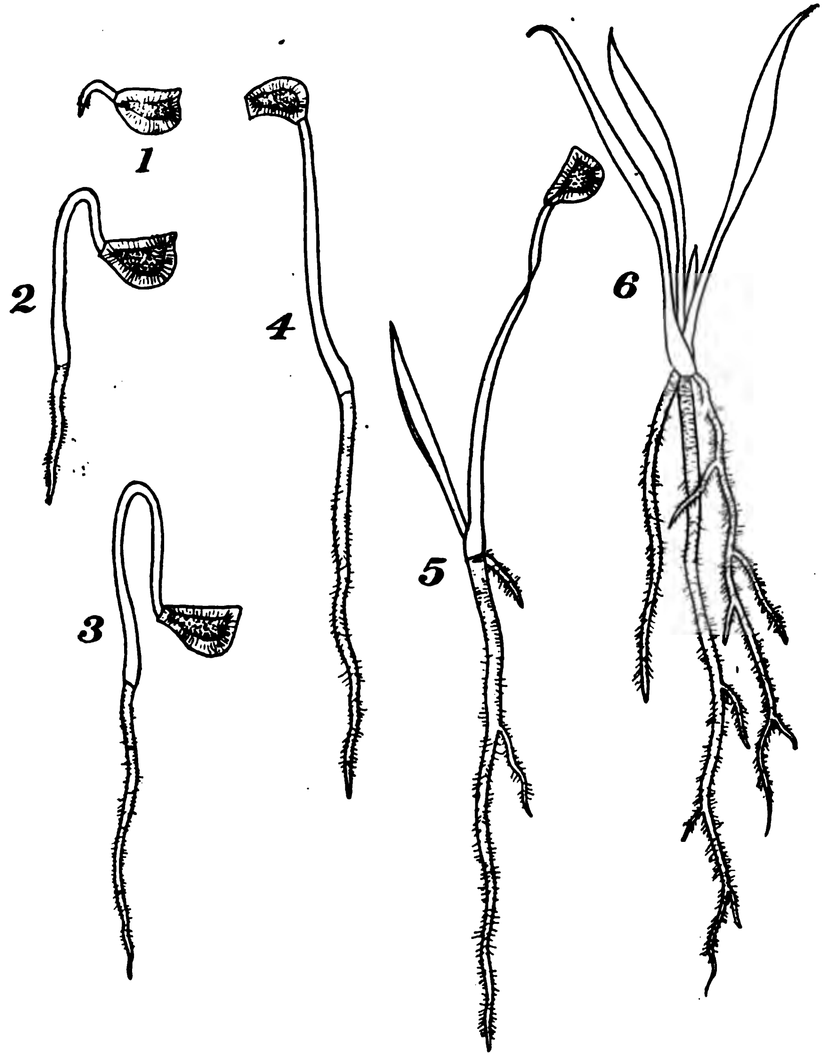

FIG. 1.—Sketches showing the various stages of development in the germination of *Lilium longiflorum*. 1. Sprouting of the seed. 2. An older stage, where the cotyledon shows the bending, while the apex remains closed in the seed absorbing the endosperm. 3. A still older stage. 4. The cotyledon has now unfolded itself, raising the attached seed high above the level of the ground. 5. The first leaf is developed while the cotyledon is as above. 6. The seed has dropped and three leaves are now developed; also two secondary roots. The roots show wrinklings above, indicating their contractile power in drawing the bulblet deeper and deeper into the soil.

it may be stated that the lily seedlings have shown great vigor where the winter temperature does not fall below 24° F. Below that point

the plants get a check to their growth and the foliage puts on an undesirable yellowish tinge, which remains during the winter.

In Florida, seed sent to persons who undertook experimental work has not given good results. The northern and central parts of the State occasionally get much too cold to insure strong winter growth. In the southern part where seed has been sent the reports of those who were experimenting are not very favorable. However, most of those who grew the seedlings were absent during the summer, in which season the growing plants need very close attention. It is possible, therefore, that the failures may be charged to want of attention at critical periods.

At Miami, Fla., the temperature is neither too hot in summer nor too cold in winter for growing bulbs. During the period from September, 1895, to December, 1903, the temperature fell below the freezing point on only two occasions, the lowest being 29° F. Under such circumstances the bulbs will do well provided they receive the necessary attention.

At Key West, Fla., the conditions are ideal, closely approaching those at Bermuda, the extreme range of temperature in thirty-three years being from 41° to 100° F. and the extreme range of precipitation 21.1 to 58.4 inches. On the large keys near the southeastern coast of Florida the seedlings do remarkably well, but the climatic and other conditions during the growing season are such as to practically prohibit good cultivators from locating there.

In the northwestern part of the State of Washington the seedlings do not stand the winter without protection. However, bulbs planted deeply in the fall make fine roots and develop well the following year, making excellent bulbs late in the season, but much too late for early forcing.

In many parts of California, especially in the hot interior valleys, where good soil and plenty of water are available and the winter temperature is not too low, the seedlings thrive well. At Loomis, a few miles northeast of Sacramento, the soil and climate are well adapted to their needs. Some areas in that vicinity are nearly frostless, and the lilies come into flower as early as anywhere in the State, with the possible exception of the foothills near Los Angeles. So far, none of the seedlings have been grown at Loomis, but judging from the growth made by mature bulbs sent for seeding purposes and comparing it with that made in other sections the advantage lies with the Loomis locality. Very little disease was apparent in the foliage, and the flowers were open several days in advance of those from bulbs planted at the same period in the valleys of the southern part of the State.

At several places south of San Francisco selected for experimental work, it was impossible to secure the carrying on of the work necessary for the raising of bulbs from seed. The seed would germinate well (fig. 1), but when it came to planting out the seedlings in spring the farmers and florists could not be brought to believe that it was possible in twelve months' time to raise a flowering plant from a seedling not more than 2 inches high. (See fig. 1, 6.) One firm had 70,000 seedlings in fine condition two years ago, but not one was put out in the field. Fortunately, however, a few capable men were found who carried out the instructions of the Department, but even then another difficulty was encountered, for when the lilies came in flower

FIG. 2.—Two-year-old bulbs from seed of *Lilium longiflorum giganteum* ♀ × *L. l. harrisii* ♂, grown at Santa Ana, Cal.

twelve months after planting the seedlings the price offered by retail florists for the blooms was a temptation which few could resist. One florist cleared $250 in the spring of 1907 for flowers from seedlings on a space 25 by 45 feet, and this was only for the flowers he did not want for seed. The removal of flowers and stems, of course, results in bulbs of an inferior grade.

Those florists who have grown the seedlings for the bulbs alone are more than pleased with the results. This has been done in the vicinity of Santa Ana, where the soil and climatic conditions are evidently very favorable. Many of the bulbs harvested were of the 7 to 9 inch grade. Figure 2 shows two 2-year-old bulbs measuring nearly 11 inches in circumference, while figure 3 illustrates a bulb which in

three years from seed measured 14½ inches in circumference when harvested, grown at Santa Ana, Cal., by Mr. Edgar A. Metcalf. The bulbs secured from these sources force well, and being almost free from disease the loss on this account is small.

At Ventura, Cal., the conditions are extremely favorable for the production of strong, healthy growth, but the bulb mite put an end to the experiment in that section the second year. It should be men-

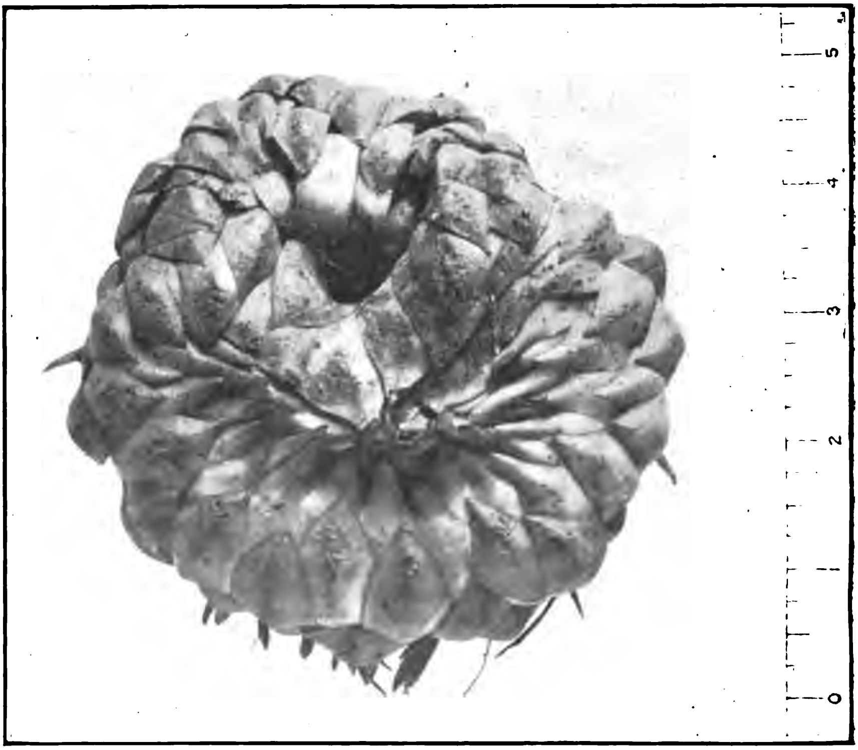

FIG. 3.—Bulb of *Lilium longiflorum giganteum* ♀ × *L. l. harrisii* ♂, three years from seed, weighing 434 grams and measuring 14½ inches in circumference when harvested, grown at Santa Ana, Cal. (Two-thirds natural size.)

tioned, however, that the soil in which the bulbs were planted had been used for calla lilies for several years.

At Longbeach, Cal., the growth made by the seedlings before planting out was very favorable, and probably a little distance from the shore in good soils the lilies would thrive well. At Yuma, Ariz., the growth made from mature bulbs planted for seeding promises well, and it is probable that the bulbs can be grown there to mature quite as early as those from the Bermudas.

In the extreme southern part of Texas the possibility of producing good bulbs would seem very encouraging, but the facilities for testing

have been anything but satisfactory. The farmers are men who grow crops on a large scale as a rule and a few hundred lilies are apt to receive but scant attention at critical periods, especially when staple crops are being attended to.

At Brownsville, Tex., one can see in the old Spanish gardens very healthy longiflorums in bloom during the first half of April. The growth is very strong and absolutely free from even a trace of disease. On January 15, 1907, some bulbs of the *harrisii* variety planted near Brownsville had made a strong growth, averaging 7 inches in height. These bloomed about the end of March and seeded fairly well.

Unfortunately, the temperature in the southeastern part of Texas is not very favorable, judging from the records supplied by the Weather Bureau. Some years the crop will turn out satisfactorily, but there always exists a danger of low temperatures, on account of which it would be unsafe to attempt cultivation on a large scale.

THE BEST VARIETIES TO GROW.

During the past three seasons in California the best success has been with seedlings which were obtained by crossing the red-stemmed *Lilium longiflorum giganteum* with *Lilium longiflorum harrisii.* (See Pl. I, and Pl. IV, fig. 1.) The progeny is remarkably strong and in some localities totally free from disease. In the open fields they come into flower about a week later than the true *harrisii.* These seedling lilies of the parentage mentioned are composed of four distinct types: Long-leafed and short-leafed green-stemmed plants, and long-leafed and short-leafed red-stemmed plants. All show a remarkable freedom of bloom. Mr. Fred. Rafferty, of Santa Ana, Cal., bloomed a large number of them in the spring of 1907. Although the seedlings were only about 3 inches high when planted out in June, 1906, some of them had 28 flowers to a single stem in June, 1907. This lot of seedlings is shown in Plates I and II. Two years ago at Ventura, Mr. S. Cole had some 2-year-old seedlings of the same cross, one of which had thirty-five flowers to a stalk. This plant is shown in Plate IV, figure 1.

On the farm of the Santa Ana Easter Lily Company during May, 1907, hundreds of plants had twenty or more flowers to a stem.

The only well-known variety which has been tried by the Department in California and Arizona is the *harrisii* variety from bulbs imported from Bermuda in 1906. These bulbs were planted in order to produce seed after being artificially pollinated. All of the stock grown turned out to be more or less diseased and most of the plants, although grown from good-sized bulbs, produced very poor flowers and a very low yield of seeds. A small lot of this variety grown from seed has turned out fairly well, but by this method of increase there are several distinct types, showing that it can not be

depended upon to produce plants true to the original type. It would seem, however, that many reliable growers in the East think there does not exist the same necessity for the *harrisii* variety as an early forcer as there was a few years ago when cold-storage bulbs were comparatively unknown for early forcing. If this is true, then there is but little need for haste in getting the *harrisii* variety into the American market, when in reality the bulbs should still be ripening in the fields. If the greenhouse men could use only the cold-storage supply for the production of flowers during the early part of the year, the fresh bulbs would then get an opportunity to ripen thoroughly before being taken from the ground. It would seem advisable to grow types from seed alone and propagate these for one or two seasons asexually, but only from bulbs and not by the scale method, using seeds instead of scales to increase the supply of bulbs. But when we have types which come absolutely true from seed there will be little likelihood of a necessity arising for saving even the smaller bulbs for replanting.

ADVANTAGES OF SEEDLINGS OVER PLANTS PRODUCED BY VEGETATIVE PROPAGATION.

The seedling method of propagation not only has its advantages in so far as the elimination of disease is concerned, but it is also a much quicker method than propagation from scales or even from small bulbs. The seedlings one year after planting very often show as many as twenty flowers to the stalk. During the past season (1907), as already stated, Mr. Fred. Rafferty, of Santa Ana, Cal., had seedlings with twenty-eight flowers. Such plants can be depended on to give bulbs of salable size the first year. Comparatively few of the 9 to 11 inch size are produced. The usual sizes are from 5 to 7 inches, but a considerable percentage of the 7 to 9 inch size is found in lots which have received good attention. The crop is ready for harvesting by the beginning of August. The smaller bulbs when replanted soon after being harvested grow much better than imported material.

THE SELECTION OF SEED BEARERS.

The seedlings now growing in California are principally crosses between the *harrisii* variety and the dark-stemmed variety of longiflorum known as *giganteum;* others are straight *harrisii* seedlings. The crosses are exceedingly vigorous and the *harrisii* plants are also more vigorous than the parents, but less vigorous than the crosses. The plants selected for bearing seed were apparently free from the disease, which manifests itself in spotted leaves, dwarfed growth, and distorted flowers.

In selecting ground for planting seed bearers it should be so arranged that lilies will not be grown on it for at least three years afterwards.

THE SELECTION OF SEEDLING TYPES FOR PROPAGATION.

The variations among the second generation seedling plants are easily recognizable. A batch of seedlings has usually four distinct kinds: Dark-stemmed (1) long-leafed and (2) short-leafed, and green-stemmed (3) long-leafed and (4) short-leafed. Three of these kinds are marked by tying on pieces of raffia, twine, and strips of rags, respectively, while the fourth series of plants remains unmarked. One kind is lifted at a time and kept separate for future propagation by division only, as it is scarcely worth while to employ the tedious method of scale propagation.

THE PREPARATION OF THE SOIL.

The preparation of the soil in the field should be attended to much in advance of the time the seedlings are ready to be planted out. If after a very heavy manuring a crop of potatoes or cabbage be taken from the ground, it will be in good order for the reception of the seedlings. In well-compacted soils a heavy crop of cowpeas or other legume deeply plowed under the previous summer should bring about good results. Immediately before planting, the soil should be worked by disking, rolling, and harrowing to make it smooth and easy to manipulate when putting in the seedlings.

BEDS VERSUS ROWS.

The question of growing the seedlings in prepared beds or in rows at equal distances apart in the field is important. The bed system requires hand work, while cultivation in rows 2 to 3 feet apart can be done with a horse machine. The beds have the following advantages: When the lilies are planted moderately close together, the foliage partly shades the ground and the lilies protect each other so that they are not likely to be whipped about by the wind; moreover, by the bed system more bulbs can be grown to the acre than in rows wide apart. The foliage of bed-grown plants is unquestionably of a deeper green than that of plants grown in rows. In irrigating, the sunken spaces or alleys separating the beds can be used to convey the water. In Bermuda the lilies are all grown in narrow beds and no irrigation is practicable, much to the detriment of the crop at times. Growing lilies in beds with hand cultivation is necessarily more expensive than in rows wide apart with horse cultivation, but it is likely to be found that the additional expense attending bed culture will be more than warranted by the returns, as this crop must not be viewed in the same manner as the ordinary field crops which yield $20, $40, or $100 to the acre. It is considered in Bermuda that an acre of lilies is not much of a success unless it yields from $1,000 to $2,000.

SIZE OF SEEDLINGS AT TIME OF PLANTING.

The seedlings at planting time are necessarily very small, having only a few very short and narrow leaves—in fact, they seem anything but promising—and to one who has not had experience in this line of work the appearance of the seedling plants would very naturally tend to discouragement. The rows in the bed should be about 8 inches apart, and the plants at least 5 inches. If the soil is loose and easily worked, they can be put in by hand; otherwise a short trowel is the handiest tool. Care should be taken not to have the seedling bed too wet at the time of transplanting, as this has a tendency to make the plants flabby. Water should be given as soon as they are put in the ground.

THE POLLINATION OF THE FLOWERS.

To insure the production of seed, the flowers must be artificially pollinated, as capsules are rarely formed without this operation. (Pl. IV, fig. 2.) The pollen is not scattered by wind to any extent and insects evidently visit the flowers without accomplishing a satisfactory transfer of pollen from the stamen to the stigmas; therefore recourse must be had to hand pollination. This consists in taking three or four stamens between the thumb and forefinger and rubbing the anthers, which are copiously supplied with pollen, against the viscid surface of the stigmas. It is best to transfer the pollen from the flowers of one plant to those of another, as the flowers then set seed better than when the pollen of one flower is transferred to the stigma of the same flower or to other flowers on the same plant.

The best time to select pollen is when the anthers have shrunk considerably and the pollen adheres to them in great masses. This should be applied to the stigmas shortly after the segments of the flowers open; the stigmatic surface will then be covered with a viscid substance which enables the pollen to adhere very easily. After pollinating the flowers on outdoor-grown plants it is advisable to cover them with paper bags. This is not necessary with plants grown in the greenhouse.

When the flower is ready for pollen it usually occupies a horizontal position, and when the pollen has performed its mission the capsule gradually assumes an upright position (Pl. IV, fig. 2), indicating that fertilization of the ovules has taken place. Not more than four capsules should be allowed to mature on one plant, as the production of seed seems to be a considerable drain on its resources.

The time required to ripen seed outdoors varies with the climatic conditions. In a greenhouse the seed ripens in about two months after

fertilization is effected. Those plants which set seed do not go to rest at the same period as those without seed capsules, but remain fresh and green for several weeks after the others have matured.

The ripening of the seed is indicated by the capsules turning from green to a light brownish color and splitting open at the top. They should then be gathered into a bag or box and spread out to dry. When dry the seeds should be removed from the capsules and stored in a cool, dry place until sown.

The plants selected for seed bearers should not be subjected to checks during the growing period. Water should be given when necessary and the ground cultivated as soon as possible afterwards. A mulch of very old stable litter helps to keep the soil cool and moist. Observance of these details will give the best seed-producing conditions; otherwise the capsules will not fill satisfactorily.

SOWING THE SEED.

The seed should be sown as soon as ripe, which is usually about the latter part of August or the beginning of September, in a place where close attention can be given to shading, ventilating, and watering. The method which has given most satisfaction in California is to sow the seed in well-prepared ground covered with a cloth house. (Pl. III, figs. 1 and 2.) This is easily and cheaply constructed, as a glance at the accompanying illustrations will show.

The roof should be high enough from the ground to provide plenty of space for a person to move around without stooping. The soil should be about 6 inches deep, on top of about 8 inches of stable manure. The bed should be raised above the surface of the ground 3 or 4 inches and edged with narrow boards a few inches above the paths; these will keep the soil in position and give a neat appearance.

The soil should consist of sandy loam mixed with screenings of dried horse manure, not for the purpose of enriching the soil, but to make it porous and easily worked. Fresh manure is injurious to the young plants. Make the surface of the beds level with a garden rake, sow the seed thinly, and press down with a piece of board. The seeds should then be covered with one-half inch of soil and cocoanut fiber in equal parts; ground redwood bark will answer the purpose quite as well, the idea being to keep the surface porous.

Water should be given through a fine sprinkler whenever the soil shows indications of becoming dry. The seeds should germinate in from three to six weeks. In April, or as soon as the weather will permit, the cloth may be removed gradually in order to harden off the young plants previous to planting out. The seeds may also be

sown in a frame built and covered so as to exclude sunshine and heavy rains while germination takes place; and while the plants are small care should be taken not to have the seed beds too wet at the planting-out period, as in this condition the seedlings are more easily wilted than otherwise when put in the field.

PRICKING OFF THE SEEDLINGS.

It is a question whether or not it pays to prick off the seedlings previous to planting in the open field. Judging from the behavior of most other crops so treated, one would suppose that it would be the best practice.

Those of the seedlings which were pricked off the past season undoubtedly showed stronger growth than those left in the seed beds till planting-out time, but it is claimed the operation does not show any beneficial effects on the plants a few weeks after being in the field. At any rate, there is much to be gained in thinning out the seedlings and pricking them off when they come up too thickly in the seed bed.

TEMPERATURE AND PRECIPITATION IN THE BERMUDAS.

For purposes of comparison with localities in the United States, the following table, showing the ranges of temperature and the precipitation at Prospect, Bermuda, for each month of the years 1900 to 1904, inclusive, will be of interest:

TABLE I.—*Temperature and precipitation at Prospect, Bermuda, from 1900 to 1904.*[a]

TEMPERATURE.

Year.		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1900	Maximum	73.4	73.4	71.8	74.2	78.4	83.0	91.2	89.8	88.6	82.6	78.6	75.8
	Minimum	53.0	50.6	48.6	49.6	56.8	61.8	67.2	68.8	59.2	64.8	59.4	53.6
1901	Maximum	71.8	70.4	73.0	74.0	83.2	88.0	92.4	93.6	91.0	87.8	74.8	74.0
	Minimum	49.2	46.8	51.4	40.4	58.6	64.0	72.0	73.0	71.4	62.2	53.8	55.0
1902	Maximum	71.6	72.0	74.2	79.8	81.2	83.6	89.4	90.0	87.4	83.8	78.0	75.0
	Minimum	49.2	48.0	49.0	55.0	59.4	63.0	67.8	67.8	69.2	62.2	62.2	54.8
1903	Maximum	74.8	74.2	74.0	74.4	76.2	84.0	90.0	90.8	90.0	81.8	77.0	76.0
	Minimum	54.2	51.0	57.0	57.2	59.6	61.4	67.4	70.2	70.0	61.6	57.4	49.8
1904	Maximum	73.4	73.2	75.4	77.4	80.6	84.4	86.4	88.0	88.0	83.4	77.0	74.0
	Minimum	46.2	45.6	50.4	53.6	60.0	65.6	68.4	69.0	67.0	64.6	58.6	54.0

PRECIPITATION.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1900	5.48	5.17	8.08	1.59	7.47	5.25	2.38	6.80	8.32	4.03	3.97	8.21
1901	9.71	5.56	8.55	7.20	1.83	1.54	2.42	2.27	1.92	10.52	7.82	3.33
1902	3.18	8.09	4.33	13.31	2.58	8.43	2.13	21.33	2.04	13.18	2.08	6.96
1903	4.37	1.44	4.06	4.20	3.98	3.83	1.73	3.85	8.38	9.83	5.08	10.58
1904	4.37	1.44	4.06	4.20	3.98	3.83	1.78	3.85	8.38	9.83	5.08	10.58

[a] Data supplied by the United States Weather Bureau.

The average normal temperature and precipitation at Hamilton, Bermuda, for each month of the years from 1900 to 1904, inclusive, follows:

TABLE II.—*Temperature and precipitation at Hamilton, Bermuda, from 1900 to 1904, inclusive.*[a]

TEMPERATURE.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1900–1904	62.0	61.5	62.2	63.9	69.4	75.0	78.4	79.6	77.4	73.0	68.7	64.7

PRECIPITATION.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1900–1904	4.94	4.44	5.13	4.18	4.66	5.96	4.44	6.08	6.51	6.71	4.38	4.49

[a] Data supplied by the United States Weather Bureau.

TEMPERATURE RECORDS OF THE LILY-GROWING LOCALITIES OF THE UNITED STATES.[a]

Fort Brown, Tex.—In the period from November, 1846, to December, 1903, at Fort Brown the annual mean was 73° F., the absolute maximum 102° F., and the absolute minimum 12° F. During the period from January, 1894, to December, 1903, with the records for several months missing, the temperature fell below 32° F. on sixty-six occasions. It would seem from these records that this vicinity would be unfavorable for growing the bulbs on a commercial basis.

Los Angeles, Cal.—The annual mean at Los Angeles from July, 1877, to December, 1903, is given as 62° F., the absolute maximum 109° F., and the absolute minimum 28° F. In the period from January, 1894, to December, 1903, the temperature fell below 32° F. on five occasions, viz, January 6, 1894; January 21, 1897; January 26 and 27, 1898; and December 13, 1901. This record was taken on roofs of the buildings of the Weather Bureau station 60 to 70 feet above the ground. Near the surface of the ground the maximum temperature is higher and the minimum considerably lower. However, in the foothills near Los Angeles frost is unknown, giving ideal conditions for lily farming.

San Diego, Cal.—At San Diego the annual mean temperature in the period from 1850 to 1903 was 61° F., the absolute maximum 101° F., the absolute minimum 32° F. During the period from January 1, 1894, to December 31, 1903, the temperature fell to 32° F. on one occasion—January 7, 1894.

Santa Barbara, Cal.—At Santa Barbara the annual mean temperature in the period from January, 1881, to December, 1903, was 60° F.,

[a] Data obtained from Bulletin Q of the United States Weather Bureau.

the absolute maximum 100° F., and the absolute minimum 28° F. During the period from January, 1897, to December, 1903, the temperature fell below 32° F. on only three occasions—December 20, 1897, February 6, 1899, and February 3, 1903. The foothill region close to Santa Barbara is practically frostless. Here we find specimens of tropical plants such as Anthuriums and Platyceriums growing out of doors all the year round; also large specimens of tropical trees such as the mango, Casimiroa, and avocado. In these places the growth of Easter lilies is continuous through the winter, and the plants flower from one to two weeks earlier than on the level ground nearer the sea.

PLATES.

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DESCRIPTION OF PLATES.

PLATE I. Field of hybrid Easter lily seedlings (*Lilium longiflorum giganteum* ♀ × *L. l. harrisii* ♂) twelve months after planting, coming into flower. These lilies were grown by Mr. Fred. Rafferty, Santa Ana, Cal., from seed supplied by the Bureau of Plant Industry. Seed sown October, 1905. Planted in the field April 30, 1906. Photographed May 30, 1907.

PLATE II. The same field shown in Plate I in bloom, after three-fourths of the flowers had been cut. Photographed June 20, 1907.

PLATE III. Raising Easter lilies at Santa Ana, Cal. Fig. 1.—Cloth house used at Santa Ana, Cal., by Mr. Fred. Rafferty in raising seedling lilies previous to planting in the field. Imported *Lilium longiflorum harrisii* plants are seen on the right. Fig. 2.—Interior of cloth house shown in figure 1, containing 100,000 seedling lilies ready for the field.

PLATE IV. Hybrid Easter lilies. Fig. 1.—Two-year-old hybrid Easter lily plant (*Lilium longiflorum giganteum* ♀ × *L. l. harrisii* ♂) with 35 flowers, grown at Ventura, Cal., by Mr. S. Cole. Fig. 2.—Capsules and seeds of *Lilium longiflorum harrisii* × ♀ *L. longiflorum* ♂.

FIELD OF HYBRID SEEDLING EASTER LILIES COMING INTO FLOWER TWELVE MONTHS AFTER PLANTING AT SANTA ANA, CAL.

THE SAME FIELD SHOWN IN PLATE I IN BLOOM, AFTER THREE-FOURTHS OF THE FLOWERS HAD BEEN CUT.

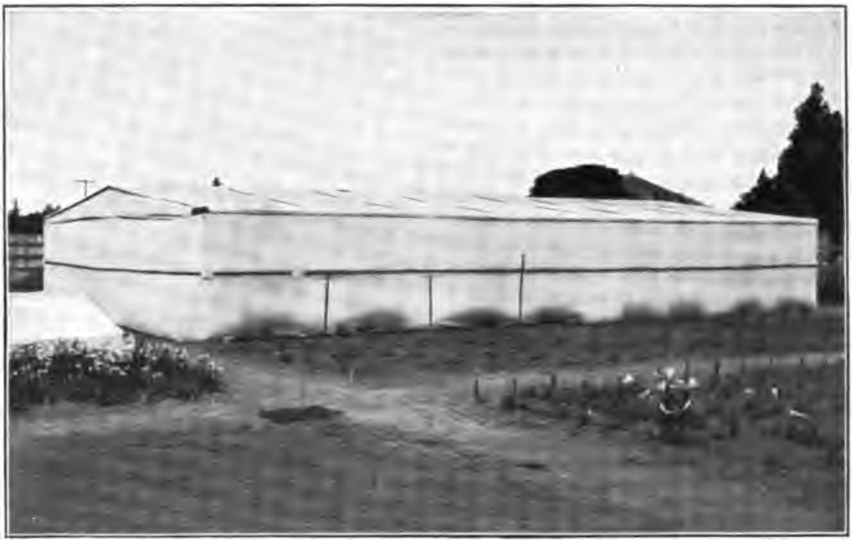

FIG. 1.—CLOTH HOUSE USED IN RAISING SEEDLINGS PREVIOUS TO PLANTING IN THE FIELD.

FIG. 2.—INTERIOR OF CLOTH HOUSE SHOWN IN FIGURE 1, CONTAINING 100,000 SEEDLINGS READY FOR THE FIELD.

RAISING EASTER LILIES AT SANTA ANA, CAL.

FIG. 1.—TWO-YEAR-OLD HYBRID EASTER LILY PLANT WITH 35 FLOWERS GROWN AT VENTURA, CAL.

FIG. 2.—CAPSULES AND SEEDS OF LILIUM LONGIFLORUM HARRISII × L. LONGIFLORUM.

HYBRID EASTER LILIES.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 121.

B. T. GALLOWAY, *Chief of Bureau.*

MISCELLANEOUS PAPERS.

I. THE SUPPOSED RELATIONSHIP OF WHITE SNAKEROOT TO MILKSICKNESS, OR "TREMBLES."

By ALBERT C. CRAWFORD, *Pharmacologist, Poisonous-Plant Investigations.*

II. MOUNTAIN LAUREL, A POISONOUS PLANT.

By ALBERT C. CRAWFORD, *Pharmacologist, Poisonous-Plant Investigations.*

III. RESULTS OF LOCO-WEED INVESTIGATIONS IN THE FIELD.

By C. DWIGHT MARSH, *Expert, Poisonous-Plant Investigations.*

LABORATORY WORK ON LOCO-WEED INVESTIGATIONS.

By ALBERT C. CRAWFORD, *Pharmacologist, Poisonous-Plant Investigations.*

IV. THE SOURCES OF ARSENIC IN CERTAIN SAMPLES OF DRIED HOPS.

By W. W. STOCKBERGER, *Expert, Drug-Plant Investigations.*

V. APPLE LEAF-SPOT CAUSED BY SPHAEROPSIS MALORUM.

By W. M. SCOTT, *Pathologist,* and JAMES B. RORER, *Assistant Pathologist, Investigations of Diseases of Fruits.*

VI. THE IMMUNITY OF THE JAPANESE CHESTNUT TO THE BARK DISEASE.

By HAVEN METCALF, *Pathologist in Charge of the Laboratory of Forest Pathology.*

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1908.

BUREAU OF PLANT INDUSTRY.

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Pathologist and Physiologist, and Assistant Chief of Bureau, Albert F. Woods.
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Investigations of Diseases of Fruits, Merton B. Waite, Pathologist in Charge.
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[a] The seven papers constituting this bulletin were issued in separate form on January 28, February 20, January 28, January 28, February 21, March 12, and February 10, 1908, respectively.

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MISCELLANEOUS PAPERS.

B. P. I.—321.

THE SUPPOSED RELATIONSHIP OF WHITE SNAKE-ROOT TO MILKSICKNESS, OR "TREMBLES."[a]

By ALBERT C. CRAWFORD, *Pharmacologist, Poisonous-Plant Investigations.*

HISTORICAL INTRODUCTION.

Many of the early settlers of the Ohio Valley, especially in Indiana and Illinois, were affected with a peculiar disorder known as milksickness, a disease which is said to have caused the death of Abraham Lincoln's mother. Persons with this disorder usually showed no mental disturbances save slight apathy, although late in the course of the disease there might be coma.

Milksickness was usually characterized by vomiting, which might be bloody, and obstinate constipation, but in rare cases this was absent.[b] So marked was this constipation that the name paralysis of the intestines was once suggested for the disorder.[c] The abdominal walls were retracted and the pulsations of the abdominal aorta could thus be easily seen. Later in the course of the disease tympanites has occurred.[d] The urinary secretion was diminished and the breath took on a peculiar fetid odor which was considered pathognomonic.

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[a] One of the most serious diseases which formerly threatened the life of man and beast in the forested parts of the Ohio Valley and adjacent territory was that known as milksickness, or "trembles." Although of late years much less trouble has been experienced, an occasional outbreak is reported.

In responding to a request that the United States Department of Agriculture investigate an attack of milksickness occurring near Peoria, Ill., a favorable opportunity was obtained to test the widespread and persistent popular belief that the plant known as white snakeroot (*Eupatorium ageratoides* L. f.) is responsible for the trouble.

After a study extending through several months, Dr. Albert C. Crawford, Pharmacologist, acting under the direction of Dr. R. H. True, Physiologist in Charge of the Poisonous-Plant Investigations of this Bureau, has shown in the results summarized in this technical paper that the eating of the plant of the white snakeroot by animals or man is not followed by the disease and that there is probably no relation between them.—B. T. GALLOWAY, *Chief of Bureau.*

[b] Crookshank, N. On the "Sick Stomach" of the Western Country, or Gastro-enteritis. Phila. Jour. Med. and Phys. Sci., vol. 12, p. 254, 1826.

[c] Dawson, J. Causes and Treatment of Milksickness. Proc. Med. Convention, Ohio, 1842, p. 48.

[d] Wood, G. B. Treatise on the Practice of Medicine, vol. 1, p. 462, 1858.

Associated with these symptoms were those of prostration, with restlessness and great thirst. Pain was referred to various localities. The temperature usually remained normal or was subnormal, rarely exceeding 99° F.[a] At times it reached 100° F. There are, however, very few recorded cases in which the temperature was actually measured by a thermometer.[b] The pulse remained about normal, but might at times be accelerated. Nothing very characteristic was noted concerning the tongue save that it was enlarged.[c] In certain cases difficulty in swallowing was reported; in others hiccough was a more or less prominent symptom.[d] No reports were made as to the condition of the pupil or of any ocular disturbances save an intolerance of light.[e]

There was said to be an incubation period of from two to ten days,[f] although apparently some cases had no such period.[g] The disease itself usually lasted from two to twenty days, but chronic cases are reported.[h] The disorder generally occurred in spring or autumn, particularly in autumn, although it might appear at any season.[i] The conditions which were especially favorable for its development were said to be those which interfered with normal excretion.[j] One attack gave no immunity, but rather predisposed to a second one.[k]

The post-mortem records are few in number. The only lesions reported are those of irritation and inflammation of the stomach and

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[a] Kimmell, J. A. Milk Sickness in America. Verhandl. d. X internat. med. Cong., vol. 2, pt. 5, p. 54, 1891.

[b] Hurd, A. Milk Sickness. Clinic, Cincinnati, vol. 9, p. 280, 1875.—Way, J. H. Clinical History, Nature and Treatment of "Milk-Sickness." Amer. Jour. Med. Sci., n. s., vol. 106, p. 310, 1893.—Yandell, L. P. Inquiry into the Nature of the Disease Called Milk-Sickness. West. Jour. Med. and Surg., 3 s., vol. 9, p. 393, 1852.—Drake, D. Memoir on the Disease Called by the People "Trembles." West. Jour. Med. and Surg., vol. 3, p. 178, 1841.

[c] Graff, G. B. On the Milk Sickness of the West. Amer. Jour. Med. Sci., n. s., vol. 1, p. 354, 1841.

[d] Coleman, A. Observations on the Disease Generally Known by the Name of the Sick Stomach. Phila. Jour. Med. and Phys. Sci., vol. 4, p. 325, 1822.

[e] Graff, G. B., l. c., p. 354.

[f] Beach, W. M. Milk Sickness. Trans. Ohio State Med. Soc., vol. 38, pp. 131, 133, 1884.—Kimmel, J. A., l. c., p. 50.

[g] Yandell, L. P., l. c., p. 394.

[h] Yandell, L. P., l. c., p. 392.—Kimmell, J. A., l. c., p. 54.

[i] Byford, W. H. Milk Sickness. Nashville Jour. Med. and Surg., vol. 9, p. 467, 1855.—Yandell, L. P., l. c., p. 379.—Beck, J. C. Milk-Sickness. North-West. Med. and Surg. Jour., vol. 14, p. 497, 1857.

[j] Phillips, W. H. Milk Sickness. Cincinnati Lancet and Observer, vol. 38, p. 142, 1877.

[k] Philips, W. H., l. c., p. 147.—Yandell, L. P., l. c., p. 392.

intestines,[a] as shown by hemorrhages into the lumen of these organs and injection of their walls, with at times adhesion of the intestinal walls to one another.[b] The pyloric region was found contracted,[c] and Peyer's and Brunner's glands were swollen. Graff has reported in one case adhesions and thickening of the cerebral membranes.[d] In other cases in which autopsies were made very slight lesions were noted.[e]

The clinical symptoms of some cases of milksickness resemble closely those described by Vaughan and Novy under the name galactotoxismus[f] and would probably be so diagnosed if they occurred outside of the areas where milksickness is prevalent. Schmidt[g] suggested that cases of milksickness occurred in cities, but were not diagnosed as such. Other cases resemble other forms of ptomaine poisoning described by Vaughan,[h] while the symptoms of still others resemble those occurring in Van Ermengem's cases of sausage poisoning. These cases described by Van Ermengem[i] showed marked nausea and vomiting and severe constipation, although two cases had diarrhea. There was retention of urine, while the temperature, pulse, and mental symptoms remained about normal, as in cases of milksickness. Some difficulty in swallowing was noted and there were ocular disturbances—diplopia, dilatation of the pupil, ptosis, etc. The post-mortem examination, as in milksickness, showed no char-

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[a] De Bruler, J. P. Milk-Sickness. Chicago Med. Jour., vol. 15, p. 209, 1858.

[b] Davis, K. H. Milk-Sickness. Atlanta Med. Reg., vol. 1, p. 394, 1881–82.

[c] Byford, W. H., l. c., p. 465.—Drake, D. Morbid Anatomy of Milksickness. West. Jour. Med. and Surg., vol. 4, 1841, p. 234.

[d] Graff, G. B., l. c., p. 366.

[e] Crookshank, N., l. c., p. 256.

[f] Vaughan, V. C., and Novy, F. G. Cellular Toxins, 1902, p. 216. Compare Graff, G. B., l. c., p. 364; also Walker, J. W., Milk-Sickness, Science, vol. 8, p. 483, 1886.

[g] Schmidt, C. H. Milk Sickness. Cincinnati Lancet and Observer, vol. 20, p. 412, 1877.

[h] Vaughan, V. C. Ptomaïnes, Toxins and Leucomaïns. Twentieth Century Practice, vol. 13.

[i] Van Ermengem, E. Ueber einem neuen anaerob. Bacillus u. seine Beziehungen z. Botulismus. Zeits. f. Hygiene, vol. 26, p. 1, 1897; Untersuch. ü. Fälle v. Fleischvergift. mit Symptomen v. Botulismus. Cent. f. Bakter., part 1, vol. 19, p. 442, 1896.—Römer, P. Ein Beitrag z. Aetiologie des Botulismus. Cent. f. Bakter., part 1, vol. 27, p. 857, 1900.—Kempner, W., and Pollack, B. Wirkung des Botulismustoxins (Fleischgiftes) und seines specifischen Antitoxins auf die Nervenzellen. Deutsch. Med. Woch., vol. 23, p. 505, 1897.—Brieger and Kempner, W. Beitr. z. Lehre von der Fleischvergift. Deutsch. Med. Woch., 1897, p. 521.—Kempner, W. Weiterer Beitrag z. Lehre von den Fleischvergift. Das Antitoxin des Botulismus. Zeits. f. Hygiene, vol. 26, p. 481, 1897.—Osler, W. Modern Medicine, vol. 1, p. 232, 1907.

acteristic macroscopic lesion. From the spleen was isolated an anærobic bacillus which could reproduce the symptoms of the disorder in animals. This organism was found in various places in the meat used in making the sausage. On culture media it developed an odor of butyric acid. The toxin obtained from these cultures would resist heating at 70° C. for a short time, but heating to 100° C. destroyed it at once. Van Ermengem mentions that in cats injected with this toxin there was muscular rigidity and that the ocular symptoms in these animals were not marked. Dogs, however, were very resistant to the action of this toxin. This organism has also been found in the fæces of hogs. A similar outbreak occurred in Darmstadt after eating vegetables infected with the same organism.[a]

No doubt the term "milksickness" has been made to embrace a variety of clinical conditions; in fact, there has been such confusion in the reports that some authors, as Yandell, have denied its existence as a peculiar entity.[b]

The mortality as given by Coleman[c] is one death in every twenty or thirty cases. Others, as Mendenhall,[d] allude to milksickness as a "very grave disease"; others, again, speak of the outlook as favorable under the proper treatment.

In the same portions of the country in which milksickness occurred a similar, if not identical, disorder also affected domestic animals, especially cattle. In them muscular tremors were present and became especially noticeable when the animals were driven, so that this disorder received the name of "trembles."[e] It was also called the "tires," on account of the disinclination of the animals to move. A rigidity of the muscles has been noted by McCall.[f] The post-mortem examination showed the gastric mucosa to be softened and the stomach and intestines contracted,[g] in some cases gangrenous,[h] and at times there was more or less peritonitis. The odor developing at

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[a] Fischer, A. Ueber eine Massenerkrankung an Botulismus infolge Genusses "verdorbener" Bohnenkonserven. Zeits. f. klin. Med., vol. 59, p. 58, 1906.

NOTE.—The bacillus *Aerogenes capsulatus* which occurs in the human intestinal tract may give rise to infections associated with constipation. See Herter, C. A., Common Bacterial Infections of the Digestive Tract, 1907, p. 207.

[b] Yandell, L. P., l. c., p. 398.—Hibberd, J. F. Observations on Milk-Sickness. Western Lancet, 1845, vol. 3, p. 448.

[c] Coleman, A., l. c., p. 325.

[d] Mendenhall, I. Milk-Sickness. Chicago Med. Jour., vol. 18, p. 435, 1861.

[e] Yandell, L. P., l. c., p. 398.

[f] McCall, A. Facts and Observations on the Milk Sickness. West. Jour. Med. and Phys. Sci., vol. 3, p. 467, 1830.

[g] Graff, G. B., l. c., p. 362.

[h] Dickey, W. Essay on Milk Sickness. Western Lancet, vol. 13, pp. 391–395, 1852.

some of these autopsies was especially offensive and was compared with the odor arising in mercurialism.[a] In one case the cerebral ventricles contained fibrin and the brain itself was surrounded by serum and pus.[b] The spinal cord in this case showed signs of inflammation. In other cases no special lesions were noted.[c]

It was proved that many cases of milksickness were communicated to man by means of milk and its products[d] or meat[e] obtained from cattle affected with the "trembles"; even the amount of cream usually added to coffee is said to have induced the disease.[f] Other cases apparently arose without the products of diseased animals being eaten, as by using contaminated water;[g] and, again, cases have occurred in vegetarians.[h] In some cases the fencing off of the suspected springs from the pasture was followed by the disappearance of "trembles" from the neighborhood. The "trembles" still appear at times, although much less common than formerly,[i] its disappearance being traced to the cultivation of the soil;[j] and it is associated with certain shady, sharply localized, wet, untilled areas. No characteristic geological peculiarity has been proved for these areas.[k] Drake met the disorder almost entirely on oak plateaus, and especially on the so-called "slashes" or marshy areas.[l] It is claimed that the

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[a] Drake, D., l. c., p. 172.—McCall, A., l. c., p. 467.

[b] Graff, G. B., l. c., p. 363.

[c] Philips, W. H. Milksickness. Cincinnati Lancet and Observer, vol. 20, p. 132, 1887.—Beach, l. c., p. 137.

[d] Drake, D., l. c., p. 194.—Wilkinson, G. W. Etiology of Milksickness. Northwest. Med. and Surg. Jour., vol. 14, p. 156, 1857.—Townshend, N. S. Milk-Sickness. Jour. Comp. Med. and Surg., vol. 4, p. 118, 1883.—Schmidt, C. H. Milk Sickness. Cincinnati Lancet and Observer, vol. 20, p. 411, 1877.

[e] Yandell, L. P. Report on Milk Sickness. Proc. State Med. Soc. Kentucky, p. 94, 1868. [Gives negative reports.]

[f] Graff, G. B., l. c., p. 359.

[g] Crookshank, N. Observations on the Milk Sickness, Cincinnati, 1840, p. 11; Sick Stomack, Ohio Med. Rep., vol. 1, p. 11, 1826.—Yandell, L. P. Inquiry into the Nature of the Disease Called Milk-Sickness, West. Jour. Med. and Surg., 3 s., vol. 9, pp. 383, 389, 1852.—Walker, J. W. Milk-Sickness. Science, vol. 8, p. 483, 1886.—Wilkinson, G. W., l. c., p. 158.—Thompson, S. W. Milk-Sickness. West Jour. Med. and Surg., 3 s., vol. 11, p. 480, 1853.—Jones, J. T. Short Essay on Milk Sickness. East Tenn. Rec. Med. and Surg., vol. 1, p. 330, 1852–53.

[h] Jones, J. T., l. c., p. 329.

[i] Connor, J. J. Further Contribution to the Subject of Milk-Sickness. Chicago Clinic, vol. 17, p. 333, 1904.

[j] Yandell, L. P., l. c., p. 387.—Walker, J. W., l. c., 540; also Trans. Indiana State Med. Soc., 1873–75, p. 128.

NOTE.—Some areas are not entirely freed by cultivation.

[k] Yandell, L. P., l. c., p. 379.

NOTE.—J. S. Seaton in his "Treatise on the Cause of the Disease Called by the People the Milksickness," p. 10, claims that he can pick out milksick areas by the geological conditions.

[l] Drake, D., l. c., p. 184.

disease is contracted by leaving the cattle in these areas over night and that the disorder can be avoided by withdrawing them from pasture before dark.[a] Corn fodder experimentally exposed to the dew in these areas communicated the disorder to a yearling.[b]

One of the peculiarities claimed for this disease is that cows will show no symptoms so long as they are milked, while their nursing calves die with typical symptoms, but when the milking ceases the cows develop the symptoms in the usual manner. In other words, the poisonous agent is partially eliminated by the milk.[c] The urine is also claimed to eliminate a portion of the poisonous body.[d] The suspected milk in some cases was noted to be of a greenish color,[e] but usually there was no characteristic noted which is peculiar to it.[f]

The disease was apparently known to the early French missionaries in the eighteenth century, but accounts of it first appeared in medical literature in 1809–10.[g] They were numerous from 1840 to 1850, but now notices seldom appear.

The etiology of this disorder has remained in doubt, and Osler,[h] in an address before the young medical officers of the United States Army, mentions its causation as one of the many intricate problems remaining to be solved. Rewards were at one time offered by several States for the solution of this question, but these do not hold at present. Opinion has been divided as to whether "trembles," or milksickness, is of parasitic origin or due to the eating of certain plants, as *Rhus toxicodendron* or *R. venenata*,[i] *Bignonia capreolata*,

[a] Beach, W. M. Milk-Sickness. Trans. Ohio State Med. Soc., vol. 38, pp. 128, 130, 1884.—Lea, W. W. Cursory Remarks on a Disease Vulgarly Called Milk Sick. Phila. Jour. Med. and Phys. Sci., vol. 2, p. 51, 1821.—Way, J. H., l. c., p. 312.

[b] Walker, J. W., l. c., p. 483.

[c] Kimmell, J. A., l. c., pp. 50, 52.—Drake, D., l. c., pp. 198, 200.—Graff, G. B., l. c., p. 360.

[d] Graff, G. B., l. c., p. 360.

[e] McCall, A. Facts and Observations on the Milk Sickness. West. Jour. Med. and Phys. Sci., vol. 3, p. 467, 1830.

[f] Graff, G. B., l. c., p. 359.

[g] Drake, D., l. c., p. 162; also West. Jour. Med. and Phys. Sci., vol. 3, p. 482, 1830.

[h] Osler, W. Aequanimitas, 1904, p. 116.

[i] Landrum, Z. C. Rhus Toxicodendron, the Cause of Milk Sickness. Atlanta Med. and Surg. Jour., vol. 7, A, p. 1, 1861.—Chase, S. C. Cause of Milk-sickness. Chicago Med. Jour., vol. 18, p. 438, 1861.—McIlhenny, J. J. Treatise on the Disease Called the Milk-Sickness, Springfield, 1843, p. 6.—Nichols, J. H. Milk-Sickness. Clinic, Cincinnati, vol. 10, p. 26, 1876.—Brewington, W. J. Milk-Sickness. Clinic, Cincinnati, vol. 10, p. 76, 1876.—Crook, J. W. Twenty Propositions on Milk-Sickness. North-West. Med. and Surg. Jour., vol. 14, p. 491, 1857.—Jones, J. T. Short Essay on Milk Sickness (*Colica trementia*). East Tenn. Rec. Med. and Surg., vol. 1, p. 324, 1852–53.

Eupatorium ageratoides, *Lobelia inflata*, etc.[a] Graff[b] eliminated arsenic, copper, etc., as causative factors and showed that small quantities of the butter or cheese (1 ounce) or of the beef (4 ounces) obtained from animals with the "trembles," if fed to a dog three times a day, would reproduce the symptoms in forty-eight hours and cause death in from three to six days; but his inoculations failed to produce the disorder. Graff adds that the poisonous principle seems to possess the power of infinite reproduction, stating, "It will be found that each pound of flesh of that animal so destroyed will possess as active powers of destruction, and will, in its turn, serve to contaminate the whole body of another animal in the same degree." Vermilya[c] claims that he was able to reproduce the disorder by feeding *Eupatorium ageratoides* and that his experiments were corroborated by Rowe, but A. W. Bitting, of Lafayette, Ind., reported to this Department his experiments in which he fed a horse 210 pounds (105 kilos) of this fresh green plant in five days without serious effect. He also fed two lambs with 80 pounds (40 kilos) without effect. Similar experiments are reported by Drake.[d] The theory of a plant poison was emphasized, as herbivorous animals were supposed to be the first affected and from them the disease transmitted to the carnivora, although the cases do not always originate in herbivora.[e]

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[a] Jerry, W. The Plant that Causes Milk Sickness. Med. and Surg. Rep., vol. 16, p. 270, 1867.—Drake, D., l. c., pp. 213–224.—Jones, J. T., l. c., p. 324.

[b] Graff, G. B., l. c., pp. 357, 360, 362.

NOTE.—Graff says the meat is active "raw or boiled," but there is evidently some mistake, as he states on page 361 that "I boiled a large quantity of the beef in pure water for several hours, and afterwards evaporated the liquid thus obtained to the consistence of cream. Although this extract contained a large quantity of gelatinous matter, with some of the other constituents of the flesh, yet, on being given in large quantities, no perceptible effect was produced."

Compton, J. W. Milk-Sickness. Indiana Med. Reporter, vol. 2, p. 255, 1881.

[c] Ohio State Board of Agriculture, 13th Ann. Rept. for 1858, 1859, p. 673.—Barbee, J. W. Facts Relative to the Endemic Disease Called by the People of the West Milk-Sickness. Western Jour. Med. and Surg., vol. 1, p. 182, 1840.—Drake, D., l. c., p. 214.

NOTE.—The view that arsenic is the etiological factor in milk-sickness has been strenuously upheld by Seaton in his Treatise on the Cause of the Disease Called by the People the Milksickness. Louisville, 1841.

[d] Drake, D., l. c., pp. 215–217.

NOTE.—The cases described by Barbee in the Western Journal of Medicine and Surgery, vol. 1, p. 182, 1840, in which dogs were killed with decoctions of this plant, seem to be merely cases of so-called salt action.

[e] Compare Jones, J. T., l. c., p. 328.

In 1843 Heeringen,[a] and later, in 1853, Heusinger,[b] compared this disorder to anthrax, and in 1858 Wood on purely literary evidence argued the presence of "a germ."[c] Byford[d] and De Bruler[e] called attention to the fact "that it undergoes multiplication in the system" and that it lost none of its virulence by passing through four successive animals. Gardner[f] and Hessler[g] claim to have found parasites in the blood, while Philips[h] compares the organism seen by him to that met with in relapsing fever. The examinations of the blood made by Schmidt were negative.[i] Molds and mushrooms also have been claimed to be the etiological factors.[j] No one has yet reproduced the disease by injection of pure cultures of organisms.

The question thus remained in doubt, with the weight of evidence in favor of a parasitic origin, when a paper by Moseley[k] appeared. As his paper attributes the origin of this disorder to the eating of *Eupatorium ageratoïdes*, or white snakeroot, it was deemed advisable to analyze his evidence, as follows:

Experiment No. 1.—This consisted in feeding a cat weighing 4½ pounds (2,041 grams) with a solution made by extracting the leaves of three or four (?) plants in one pint (473 c. c.) of milk. After taking about one-half gill (59 c. c.) of this extract the animal showed tremors and dullness and was found dead in about twenty-six hours. The post-mortem examination proved to be negative. It is possible in this case that bacteria may have developed in the milk and produced poisonous compounds before feeding. This experiment was performed by Moseley's assistant and the animal was not seen by him until after death.

Experiment No. 2.—A tramp kitten of unknown history weighing 30 ounces (850.5 grams) was fed with a decoction made from one-half

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[a] Heeringen, E. Discovery of the True Cause of the Disease Called by the People Trembles, or Milksickness, Louisville, 1843.

[b] Heusinger, C. F. Recherches de Path. Comp., vol. 1, p. 126, 1853.

[c] Wood, G. B., l. c., p. 465.

[d] Byford, W. H., l. c., p. 467.

[e] De Bruler, J. P., l. c., p. 209.

[f] Gardner, J. Milk-Sickness. St. Louis Med. and Surg. Jour., vol. 38, p. 290, 1880.

[g] Hessler, R. Preliminary Notes on an Almost Extinct Native Disease, Trembles or Milk-Sickness. Proc. Indiana Acad. Sci. for 1905, p. 122.

[h] Philips, W. H., l. c., p. 139.

[i] Schmidt, C. H., l. c., p. 412.

[j] Wilkinson, G. W., l. c., p. 159.—Howard, E. J. Mukosma. Indiana Jour. Med., vol. 2, p. 370, 1871.—Borland, S. Essay on the Milk Sickness, p. 27, Little Rock, 1845.—Drake, D., l. c., p. 218.—Johnson, J. M. Milk-Sickness. Atlanta Med. and Surg. Jour., vol. 7, B, p. 293, 1866. Compare also Mitchell, J. K., Five Essays.

[k] Moseley, E. L. The Cause of Trembles in Cattle, Sheep, and Horses and of Milksickness in People. Ohio Naturalist, vol. 6, pp. 463 and 477, 1906.

pound (226.8 grams) of the fresh plant and also some milk extract of the plant, more of the plant than the first (a larger cat) received. The cat was dull and showed tremors at times after the first feeding, but the appetite remained good, and eleven days later trembling could still be seen. Eighteen days later the animal was fed on the carcass of a rabbit which had died after eating the same plant (see experiment No. 6). This rabbit had died three days before the feeding of the cat began. Some tremors were seen in the cat, but it ate and continued active for three days, when it was killed. This experiment is open to the objection that nothing was known of the cat previous to the feeding, and cats often show slight tremulous movements of the cutaneous muscles. Then again, granting that the tremors were due to eating the meat, no record is made of having preserved the rabbit meat on ice, and decomposition may already have begun, and the mere presence of muscular tremors of unknown origin without the other clinical symptoms does not indicate the disease known as "trembles."

Experiment No. 3.—A cat whose previous history was not given was fed on the same carcass given to the cat referred to in experiment No. 2, and on that referred to in experiment No. 7, after it had stood two days, and the feeding was continued three days; then it was fed on a similar rabbit two days after death. This animal showed tremors and died in twenty days. The temperature of this animal rose about 2¼° F. on the third day before death. The buttocks were reported soiled, so evidently it had no marked constipation. Now, constipation is a symptom which Kimmell, Drake, Chesney, Graff, and others had previously noted in animals affected with the "trembles," and is one of the characteristics of milksickness.[a] Post-mortem examination showed two ounces of *acid* fluid in the peritoneal cavity.

Experiment No. 4.—A cat which was sick before beginning the experiment was fed with a milk extract of the plant, but only showed light symptoms (diarrhea) and "was seen to tremble only a few times and then under conditions which might probably have produced trembling without the aid of any poison." This animal was then fed on meat from one of the rabbits used in previous experiments. Moseley said that "the meat seemed to affect him more than the milk."

Experiment No. 5.—A dog was fed on an aqueous extract of the plant mixed with milk and some chopped-up plant mixed in hash and showed some trembling and weakness, but Moseley adds "he was not so different from usual except in the early morning but what all these things might have escaped notice if he had not been watched." In other words, an animal which Graff had shown to be very susceptible

[a] Chesney, J. P. Milk Sickness. St. Joseph Med. and Surg. Rep., vol. 1, p. 99, 1880.—Kimmell, J. A., l. c., p. 51.—Drake, D., l. c.; cow, p. 170; horse, p. 173; dog, p. 174.—Graff, G. B., l. c., p. 360.

to the "trembles," when fed with *Eupatorium ageratoides*, the supposed carrier of the disease, showed practically no symptoms. He then adds the remarkable report of his assistant: "While I held the dog's mouth open a friend poured the extract into the dog's mouth. The dog choked and coughed the extract into my face and mouth. I was in a room while the mixture was steeping and also on the previous evening. At 10.30 I was taken with a fit of cramps and the following day was nauseous. Several times during the three following days I had fits of trembling, always accompanying the extension of limb." In this connection it may be stated that the present writer's laboratory assistant and himself squeezed their material by hand, handled it, and made their own extracts in a rather close room without experiencing any such effects.

Experiment No. 6.—In this case 2 ounces (56.7 grams) of the snakeroot was placed in the cage with a rabbit. The rabbit died in three days. No tremors had been noted. This case can be excluded because of the absence of any accurate clinical report or histological examination, as rabbits are very apt to die of intercurrent diseases, especially coccidiosis.

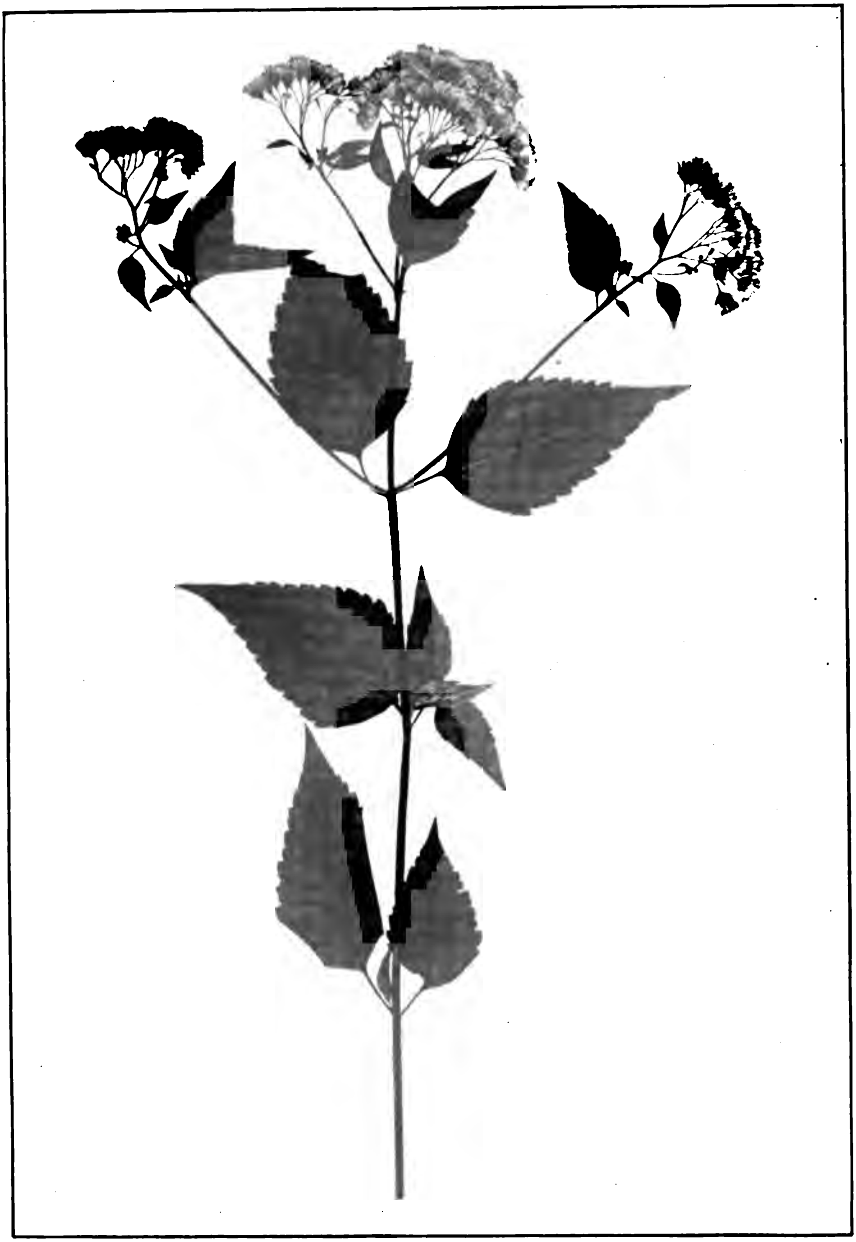
Experiment No. 7.—This is of the same type as experiment No. 6, and open to the same objection. Moseley merely quotes the report of his pupil as to the presence of tremors.

Experiment No. 8.—This experiment consisted in injecting subcutaneously into a rabbit weighing 1,383 grams an aqueous extract of 3 grams of the plant. This injection was followed by tremors. Three days later the animal was fed with 2 to 3 ounces (57.7 to 85 grams) of the leaves and branches, and died in one hundred and twenty hours. There was no constipation. Moseley says, "The effects on her actions and appearance were not striking and might have escaped notice if I had not looked for them."

Experiment No. 9.—A rabbit was fed for three days with an aqueous extract of the plant. The only result noted was a "tremulous motion of the sides, with more rapid respiration." This animal was then fed with a milk extract of the plant. No constipation resulted, but the same trembling was seen, and save for a slight lessening of strength "she has seemed well."

Experiment No. 10.—This experiment consisted in feeding a milk extract of the plant, but with only slight action. A rabbit was reported to tremble after eating 67 grams of the leaves and branches of a fresh plant, but survived.

Experiment No. 11.—A young lamb weighing 40 pounds (18.14 kilos) was fed with the leaves of this plant. The animal showed trembling and died in four days, having eaten about 29 ounces (822 grams). There was no constipation. The kidneys were found to be



FLOWERING BRANCH OF WHITE SNAKEROOT (EUPATORIUM AGERATOIDES, L. F.).

much enlarged, weighing about twice as much as normal. One can form no positive opinion as to the cause of death. The enlarged kidneys, taken in connection with the history of convulsions and fluid in the peritoneal cavity, might suggest a nephritis.

Six ounces (170 grams) of the liver of this animal were fed to a cat. This cat showed merely a few tremors. A second cat also ate 6 ounces (170 grams) of the muscles but showed no tremors, and a dog after eating 4 ounces (103.4 grams) of the liver showed no symptoms save some dullness, but after feeding on the heart and spleen some tremors were noticed. None of these animals died.

These experiments, taken in the light of Graff's work, indicate that the sheep had not the disease commonly known as "trembles."

Moseley explains the lack of results in some of his experiments by the existence of a hypothetical immunity, but cases of milksickness are known not to possess immunity—in fact, one attack rather predisposes to another, so that it can not be said that Moseley has even proved *Eupatorium ageratoides* to be a poisonous plant, much less the cause of "trembles."

RECENT INVESTIGATIONS.

In the month of August, 1906, a rather serious outbreak of milksickness, or as it is frequently called in the case of stock "trembles," occurred in the vicinity of Minooka, Ill., resulting in the death of about 50 head of cattle. The office of Poisonous-Plant Investigations was asked to undertake an investigation into the cause of the trouble. In view of the fact that only plants as popularly understood are the subject of investigation by this office, only plants were studied. The widespread and popular belief that the eating of the white snakeroot (*Eupatorium ageratoides*), illustrated in Plate I, is the cause of the trouble seemed to direct the principal efforts of the investigations toward that common plant. It was found in considerable quantities in pastures in which the animals were supposed to have contracted the disease, and in a number of patches the plants had been browsed, presumably by the stock. Material from these patches, both dried and in chloroform water, was preserved for study.

EFFECT OF WHITE SNAKEROOT ON RABBITS.

EXTRACTS FROM DRY PLANT.

To prepare the material for use, 200 grams of the dry herb were extracted with cold water and the extract evaporated to the desired concentration in vacuo at about 55° C. When such an extract was fed to a rabbit weighing 4 pounds 2 ounces (1,871 grams) no symptoms were noted, either immediately or on the following day. Two days after the first dose a like quantity was again administered and no

symptoms appeared, the rabbit weighing 4 pounds 5 ounces (1,956 grams). After receiving three further doses, representing 200 grams each, in a period of five days the animal showed no symptoms of "trembles" or of suffering of any sort, the weight increasing under this treatment to 4 pounds 8 ounces (2,041 grams). The animal which had received this treatment gave normal delivery to young and made a rapid recovery, the young appearing abnormal in no respect. Thus, although the rabbit received the equivalent of 1,000 grams of the plant in a week, no symptoms of milksickness appeared and the animal steadily gained in weight.

After a rabbit weighing 4 pounds (1,814.3 grams) was injected subcutaneously in the back with an extract of 20 grams of the dried plant muscular tremors were felt in the limbs and in the masseter muscles, but recovery followed.

When a quantity of the same extract representing 40 grams was injected into a rabbit weighing 4 pounds 1 ounce (1,842.7 grams) no results followed, but an extract of 60 grams of the dried plant proved fatal in about twelve hours, the animal showing distinct tremors.

Following the injection of an aqueous extract representing 5 grams of the dried plant into a rabbit weighing 3 pounds 8 ounces (1,587.5 grams) there were no tremors and the rabbit was apparently normal, though the temperature rose 2.2 degrees F. in two hours and twenty-five minutes after the injection.

A rabbit weighing 3 pounds 12 ounces (1,700.8 grams) was injected subcutaneously with a concentrated extract representing 10 grams of dried Eupatorium and no tremors resulted, but in the two and one-half hours following the injection a fall of one-half a degree in the temperature was noted. Death followed during the night.

On increasing the quantity of extract until it represented 20 grams of the dried plant and injecting this subcutaneously, slight tremors were felt on careful examination by the hand over the hips after almost an hour and a half. An hour and forty minutes later no tremors were felt and the rabbit seemed normal. The temperature two and one-fourth hours after injection fell 2 degrees F. Death ensued during the night.

These animals had been kept under observation for two weeks preceding the experiment and had shown nothing abnormal.

EXTRACTS FROM FRESH PLANTS PRESERVED IN CHLOROFORM.

To prepare extracts from material preserved in chloroform the fresh plant was placed in a container and covered with water containing enough chloroform to prevent fermentation. When wanted for use the liquid was pressed out of the plant and concentrated in vacuo to the

proper degree. An extract representing 109 grams of the dried plant weighed after extraction (perhaps about 400 grams of the fresh plant) was given by mouth to a rabbit weighing 3 pounds 5 ounces (1,502.5 grams), but no symptoms were observed.

After a similar extract representing 127 grams of dry residue had been injected subcutaneously into the back of the same rabbit distinct tremors were shown in the hips and masseter muscles. Death followed during the night. No enlargement of the kidneys was seen.

EXTRACTS FROM ASH.

The method of preparation of extracts from ash was as follows: Ten grams of the dry herb were ashed in a platinum bowl and the ash washed into a porcelain bowl and carefully treated with acetic acid to decompose the carbonates, then evaporated to dryness and treated with water. The free acid was removed by repeated evaporation. The residue was treated with water, but not all dissolved, perhaps owing to the formation of basic salts. An emulsion consisting of the solution with the undissolved portion when injected subcutaneously produced marked tremors in the hips in rabbits after an hour and a quarter, and later in the masseter muscles. A marked acceleration of the respiration was also observed. After one and three-fourths hours the masseter muscles still twitched, but after two and one-fourth hours slight, if any, tremors were seen. No tremors were noted on the following day.

In ashing plants a large portion of the calcium-barium group will unite with the oxidized sulphur, forming insoluble sulphates, and thus be rendered inactive physiologically. Thus, trembling resulted from the injection of less of the inorganic salts than corresponds to 10 grams of the dry plant. This muscular twitching is well known to result from the hypodermic injection of certain salts (sodium, etc.), but not after administration by mouth.

An injection of a similar extract from 20 grams of the plant also produced the same result.

EFFECT OF WHITE SNAKEROOT ON CATS.

After an extract prepared from chloroform-preserved material corresponding to 50 grams of the dry plant residue was fed to a cat weighing 1 pound 8 ounces (680.3 grams), emesis followed in about fifteen minutes. When an aqueous extract corresponding to a dry plant residue of 39 grams was evaporated to 32 c. c. and 7 c. c. of this extract were fed twenty minutes after the emesis referred to and 11 c. c. were given thirty-five minutes later, urination and defecation followed promptly with renewed emesis in about ten minutes. Thirty

minutes after the administration of the last dose of extract 14 c. c. more were fed, emesis again resulting in about eight minutes, followed about fifteen minutes later by further efforts toward elimination by the intestines. Since in both dogs and cats emesis is especially easy, no especial significance is to be attached to that phase of the results. No tremors resulted and the appetite remained as usual.

In order to reduce the liability to emesis which may follow the administration of large doses, smaller quantities of the extract were given. If 7 c. c. of an extract concentrated to 32 c. c., representing a dried plant residue of 39 grams, were fed, no emesis followed for three hours. On taking a further dose of 8 c. c. the animal vomited within ten minutes. However, five minutes after this, slight movements of the skin could be seen, but these were apparently only such cutaneous movements as are commonly observed in cats. After 6 c. c. more were fed emesis soon followed. The same result followed the feeding of 11 c. c. after a period of about fifty minutes.

During the course of feeding with Eupatorium extracts as above indicated, the cat gained an ounce in weight in a week, showing normal appetite and evacuations. After four days more the weight increased about 5½ ounces (155.8 grams).

After a further interval of two weeks without treatment, when a concentrated extract representing 35 grams of plant was fed, no tremors or other abnormal symptoms were to be noted, although the animal was kept under careful observation. When, on the day following, an extract representing 65 grams was given no symptoms whatever followed other than evidence of a somewhat laxative action, and the cat continued to increase in weight. This animal gained 219 grams during the month it was kept under observation.

EFFECT OF WHITE SNAKEROOT ON DOGS.

An extract of Eupatorium representing 23 grams of the dried plant preserved in chloroform when fed to a dog kept under careful observation produced no symptoms, and the appetite remained normal; temperature before feeding, 100.6° F. . When, twelve days later, a concentrated aqueous extract representing 200 grams of dried plant was given to the same dog, weighing 14 pounds 12 ounces (6,690.4 grams), having a temperature before feeding of 101° F., no symptoms resulted, the temperature after one and one-half hours registering 102° F. No symptoms appeared during observation for three more days, the weight increasing to 15 pounds 5½ ounces (6,959.8 grams). Eleven days later the weight increased to 16 pounds 15 ounces (7,682.7 grams). The animal was very playful throughout the investigation.

EFFECT OF WHITE SNAKEROOT ON SHEEP.

A lamb weighing about 25 kilos when fed 58 grams of the fresh plant showed merely some diarrheal symptoms.

EFFECT OF WHITE SNAKEROOT ON MAN.

The writer became so convinced of the harmlessness of the plant that he decided to take the plant extract himself. Four hundred grams of the fresh *Eupatorium ageratoides* were collected at Landover, Md., under the supervision of Prof. C. F. Wheeler, one of the botanists of the Department of Agriculture, and extracted carefully with water, chloroform being used as a preservative. This extract was evaporated in vacuo and made up to 154 c. c. At 11.10 a. m., September 30, 1907, 14 c. c. of this extract were taken. Seventy-four c. c. in all were taken by 1.45 p. m., without any special symptoms. The taste of the extract was exceedingly disagreeable. By 4.15 p. m. all but 40 c. c. had been taken; that is, an extract of over 300 grams. No untoward symptoms characteristic of milksickness were noted the following day; in fact, the writer never felt better.

To simulate the conditions which occur in herbivora, 100 grams of the dried plant from Illinois were digested with pepsin and pancreatin and the concentrated products taken by the writer in the period of one hour without the production of any serious symptoms.

SUMMARY.

To sum up, it certainly can not be said that it has been proved that milksickness is due to any constituent of *Eupatorium ageratoides*. The transmission of the disease by eating small quantities of meat or milk of animals sick with the "trembles" and the fact that cooked meat or boiled milk [a] does not produce this disorder point primarily rather to a parasitic origin, while the fact that *Eupatorium ageratoides* [b] is abundant in areas where the disease is not known and absent in some milksick areas [c] also indicates that the plant has no relation to the disease. If it does, it would be only an accidental carrier of some pathogenic organism.[d] According to reports, the same flora may be in the areas in which "trembles" occur as in those free from it, and milksickness is also said to occur where no vegetation grows (inclosed pens).[e] The disease also has disappeared from an area

[a] Smith, C. H. Milk Sickness. Boston Med. and Surg. Jour., vol. 77, p. 471, 1867–68.—Wood, G. B. Practice of Medicine, vol. 1, p. 465, 1858.

NOTE.—Some toxins from infected meat are not injured by boiling.

[b] Wilkinson, G. W., l. c., p. 153.—Graff, G. B., l. c., p. 361.

[c] Brewington, W. J. Milksickness. The Clinic, Cincinnati, vol. 10, p. 77, 1876.

[d] Walker, J. W., l. c., p. 483.

[e] Wilkinson, G. W., l. c., p. 153.

after simply clearing the woodland where it occurred and turning it into pasture.[a] Again, severe epidemics have occurred in winter when the foliage has disappeared, which would tend to exclude the higher, non-evergreen plants as the cause of this disorder. In fact, all the evidence in hand is against the causation of this disease by such plants, and certain analogies with cases of botulismus suggest a somewhat similar cause. If there is any truth in the statement that cattle exposed in pasture to night air especially contract the disease, this fact might suggest the more or less direct connection of some night organism as a carrier of the parasite, and certain parasites are supposed to be associated with certain localities.

Very little is known chemically of *Eupatorium ageratoides.*

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[a] Heeringen, E., l. c., p. 9.

NOTES.—A full bibliography can be found in Schuchardt, B., Die Milchkrankh. d. Nord Amerikaner, Janus, vol. 2, pp. 437, 525, 1897–98.

The most interesting experimental paper is that of Graff, while that of Drake is valuable for its fund of personal experiences as told by the settlers, and that of Schuchardt is the best literary handling of the question.

Eupatorium perfoliatum, a closely allied plant, has received some chemical attention, and a nonnitrogenous body, eupatorin, has been obtained. While the author states it will kill mice on subcutaneous injection, he fails to give the dose, and nothing can be drawn from this report as to its physiological activity.

Shamel, C. H. Eupatorin: The Active Principle of Eupatorium Perfoliatum. Am. Chem. Jour., vol. 14, p. 224, 1892.

Latin, G. Eupatorium Perfoliatum. Pharm. Jour. and Trans., 3 s., vol. 11, p. 192, 1881.

MOUNTAIN LAUREL, A POISONOUS PLANT.[a]

By ALBERT C. CRAWFORD, *Pharmacologist, Poisonous-Plant Investigations.*

HISTORICAL INTRODUCTION.

Many members of the Ericaceæ, or heath family, contain principles which are injurious to man and to animals. Of these the members of the genus Kalmia especially interest us on account of their wide distribution in the United States and from the fact that many cases of poisoning in animals have been attributed to them. This genus is American in origin, but is found mainly in the Eastern States. The members of this group received their generic name in honor of Peter Kalm, but their popular name, laurel, was given on account of the resemblance of their leaves to those of the English laurel tree, a member of an entirely different family.[b] On account of the beauty and perfection of their flowers they were once proposed as a national emblem.[c]

Of these, mountain laurel (*Kalmia latifolia*), shown in Plate II, is probably the most important. North of Maryland it is usually known as mountain laurel, while south of Maryland it is sometimes known as ivy.[d] It has also received many other names, as calico bush,[e] laurel,[f] sheep laurel, mountain ivy,[g] wintergreen, great laurel,[h]

[a] The mountain laurel, *Kalmia latifolia* L., has long been recognized by many people as one of our most deadly shrubs. It is a poison fatal to live stock, especially to sheep and goats, which seem more likely than cattle and horses to browse on it. The Bureau of Plant Industry is in receipt of letters inquiring into the facts concerning its action and the methods of treating poisoned stock.

Dr. Albert C. Crawford, Pharmacologist, under the direction of Dr. Rodney H. True, Physiologist in Charge of the Poisonous-Plant Investigations of this Bureau, has given the matter laboratory study with the results here briefly stated.—B. T. GALLOWAY, *Chief of Bureau.*

[b] Kalm, P. Travels into North America, 2d ed., vol. 1, p. 263, London, 1772.

[c] Bailey, L. H. Cyclopedia of American Horticulture, 4th ed., vol. 3, p. 854, 1906.

[d] Gronovius, J. F. Flora Virgin., pt. 2, p. 160, 1743.

[e] Coulter, S. Catalogue of Flowering Plants * * * Indigenous to Indiana. Dept. Geol. and Nat. Resources of Indiana, 24th Ann. Rept., 1899, p. 607.

[f] Gronovius, J. F., l. c., p. 160.

[g] Smith, J. E. Natural History of the Rarer Lepidopterous Insects of Georgia, vol. 1, pl. 73, 1797.

[h] Cutler, M. Account of Some of the Vegetable Productions Naturally Growing in This Part of America. Amer. Acad. Arts and Sci. Mem., vol. 1, p. 442, 1785.

American laurel,[a] wicky, rose laurel, etc. The Pennsylvania mountain laurel[b] (*Rhododendron maximum*) is a closely allied species, while in California the name mountain laurel is applied to *Oreodaphne californica*,[c] a member of the family of Lauraceæ.

Mountain laurel usually occurs as a shrub, growing from 5 to 15 feet high, but in the Blue Ridge Mountains of North Carolina it has been seen reaching to a height of 25 or 30 feet.[d]

The species extends from New Brunswick and Canada to Florida, and through the Gulf States to Louisiana and Arkansas, but is especially abundant through the Eastern States along the Allegheny Mountains, where it forms dense, impenetrable thickets.[e] In spite of the name "mountain laurel" it grows on hills and banks in the lowlands, but especially along the courses of streams. The leaves are of a tough, leathery consistency and are evergreen. The flowers, which are nearly destitute of odor, have a peculiar arrangement of their stamens, which bend over with their brown anthers projecting into pockets in the corolla,[f] so that when this flower is visited by a bee they fly back, scattering the pollen over its own stigma, and also over the insect, which then carries it to other flowers, securing cross pollination. The flowers have a waxlike appearance and vary from a white to a rose color. The wood of the mountain laurel is close grained and hard and is a substitute for boxwood, and it may be used for making handles of small tools, etc.[g] The powder covering the leaves has been used as a snuff.[h] The laurel leaves have been utilized ever since the time of the colonists as one of the evergreens for Christmas decorations.[i]

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[a] Coulter, S., l. c., p. 607.

[b] Marshall, H. Arbust. Amer., p. 127, 1785.

[c] Reports of Explorations and Surveys * * for a Railroad from the Mississippi River to the Pacific Ocean, 1853–54. Senate Doc., 2d Sess., 33d Cong., vol. 13, pt. 4, p. 133, 1856.

[d] Aaron, C. E. Our Common Poisonous Plants. Cram's Magazine, 1900, vol. 2, p. 502.

[e] Sargent, C. S. Report on the Forests of North America, 10th Census, p. 98, 1884.

[f] The details as to the historical structure of this plant will be found in the following works:

Paschkis, H. Contributions to a Closer Knowledge of Some Little-Known Leaves. Pharm. Jour. and Trans., 3d ser., vol. 12, p. 86, 1881–82. Also Zeits. d. allg. oest. Apoth.-vereines, vol. 18, p. 434, 1880.

Breitfeld, A. Der anatom. Bau d. Blätter der Rhododendroideæ in Beziehung zu ihrer systematischen Gruppirung und zur geographischen Verbreitung. Botan. Jahrb., vol. 9, p. 319, 1887–88.

Vesque, Julien. Caractères des Principales Familles Gamopétales Tirés de l'Anatomie de la Feuille. Ann. des Sci. Naturel. Botan., 7th ser., vol. 1, p. 240, 1885.

Solereder, Hans. System. Anatom. d. Dicotyledonen, 1899, p. 541–551.

[g] Emerson, G. B. Trees and Shrubs of Massachusetts, vol. 2, p. 445, 1875.

[h] Browne, D. J. Trees of America, p. 364.

[i] Kalm, P., l. c., p. 264.

FLOWERING BRANCH OF MOUNTAIN LAUREL (KALMIA LATIFOLIA, L.).

Notices of this plant occur in the early botanies[a] and books of American travel. Capt. John Smith describes, in his Generall Historie of Virginia, 1624, volume I, page 10, a "Kinde of tree like Lowrell," while Hudson in 1609 mentions "rose trees" as occurring on Cape Cod. Catesby describes it under the name Chamaedaphne foliis tini, floribus bullatis umbellatis, and says distinctly that "When cattle and sheep, by severe winters deprived of better food, feed on the leaves of these plants, a great many of them die annually."[b] The Delaware Indians are said to have used a decoction of these leaves for suicidal purposes.[c]

Public attention was especially called to this plant by Peter Kalm, the Swedish botanist, after whom Linnæus named the genus Kalmia. He described it under the name "spoon tree," because the Indians at that time made spoons of this wood. During his travels in America in 1748 he noted that calves which had eaten of the leaves became "sick, swelled, foamed at the mouth, and could hardly stand," and reported from the observations of the colonists that sheep, especially young ones, died very quickly after eating of these leaves, and that horses, oxen, and cows were made sick but seldom died, as these animals ate only small quantities of the leaves. Deer and partridges were said to feed on the leaves with impunity, and the venison from these deer was harmless to man.[d] A snake was said to have been killed by dropping a tincture of this plant on its back.[e]

John Bartram, an early American botanist, was an ardent lover of, and writer on, mountain laurel, and by him it was brought to Collinson's attention, who then introduced it into England about 1734.[f] It would seem more appropriate to have named the genus after him,[g] as his work antedated that of Kalm. During General

[a] Van der Donck, A. Vertoogh van Nieu Nederland, 1650. Translated by H. C. Murphy, 1854, p. 19.—Plukenet, L. Almagest. botan., 1769, p. 106; Almagest. botan. Mantissa, 1769, p. 49.—Gronovius, J. F., l. c., p. 160.—Linnæus, C. Spec. Plant., Ed. Willdenow, vol. 2, p. 600, 1799. Spec. Plant., vol. 1, p. 393, 1753. Amœn. Acad., vol. 3, p. 13, 1764.—Trew, C. J. Plantæ Selectæ, 1750, pl. 38. Ray, J. Hist. Plant., vol. 2, p. 1927, London, 1688. [Bannister's list of 1680.]—Hudson, H. Discourse. Collections of the New York Historical Society for the Year 1809, vol. 1, p. 121.

[b] Catesby, M. Natural History of Carolina, vol. 2, p. 98, 1743.

[c] Barton, B. S. Some Account of the Poisonous and Injurious Honey of North America. Amer. Phil. Soc. Trans., 1802, vol. 5, p. 61.

[d] Kalm, P., l. c., pp. 264–265.

[e] Barton, B. S. Collections for an Essay towards a Materia Medica of the United States, pt. 2, p. 27, 1804.

[f] Aiton, W. Hortus Kewensis, vol. 2, p. 64, 1789.—Catesby, M., l. c., p. 98.

[g] Darlington, W. Memorials of John Bartram and Humphry Marshall, pp. 130, 141, 228, etc., Philadelphia, 1849.—Bartram, John. Observations, London, 1751, pp. 26 and 69.

Braddock's campaign against the French and Indians in 1755 many horses[a] were lost from eating mountain laurel. The plant was introduced into France by Michaux.[b] In 1802 George G. Thomas[c] performed some experiments with *Kalmia latifolia* and *K. angustifolia* on himself, on a friend, and on some dogs. These experiments he embodied in an inaugural dissertation which was presented to the University of Pennsylvania. Six to 15 grains (0.4 to 1.0 gram) of the dried leaves produced distinctly unpleasant symptoms—rapid pulse, a feeling of fullness with pain in the head, throbbing of the temples, with nausea, vomiting, and dilatation of the pupils. In dogs the administration of a decoction of 30 grains (2 grams) was followed by marked salivation, with stupor, rapid respiration and purgation, paralysis, and finally convulsions. Thomas made the interesting observation that if the laurel was mixed with lard the toxic symptoms were much lessened. He examined the distillate from the leaves for an essential oil, but failed to find any.

After Thomas, several experimenters reported on the action of mountain laurel upon themselves. Bigelow,[d] who saw the dried leaves taken in doses up to 20 grains without producing symptoms, questioned if the leaves had a specific action, and traced any injurious effect they might exert to their indigestibility. Others, as Osgood,[e] Stabler,[f] and an anonymous author in the Boston Medical and Surgical Journal, volume 10, page 213, reported severe symptoms on themselves.

This action was compared with that of Veratrum.[g] From this time on few reports of experiments were published, yet the number of cases of poisoning in stock reported to the Department of Agriculture induced the Commissioner to call attention to this subject in his report of 1863.[h] Sheep are the animals usually reported as affected by the plant. Under ordinary conditions, however, eastern-bred sheep will not eat the plant unless they are starved or their supply of green or attractive food has been cut off.

As is well known, most of the cases of poisoning occur in winter,[i] when the laurel is the only green plant around, although western-bred

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[a] Barton, B. S., l. c., p. 60.

[b] Browne, D. J. Trees of America, p. 364.

[c] Thomas, G. G. Inaugural Dissertation on the Kalmia Latifolia and Angustifolia, Philadelphia, 1802.

[d] Bigelow, J. Amer. Med. Bot., vol. 1, p. 140, 1817.

[e] Bigelow, J., l. c., vol. 3, p. 185, 1820.

[f] Stabler, R. H. On Kalmia Latifolia. Amer. Jour. Pharm., n. s., vol. 10, p. 241, 1845.

[g] Medical Properties of the Kalmia Latifolia. Boston Med. and Surg. Jour., vol. 10, p. 213, 1834.

[h] Report of the Commissioner of Agriculture for 1863, p. 242.

[i] Remarkable Instance of the Absence of Animal Instinct. Penny Magazine, vol. 7, p. 283, 1838.

sheep if suddenly turned into a laurel area may eat it at any time. As the leaves are tasteless and of a tough, leathery consistency, it is very evident why animals will not eat the plant under ordinary conditions.

A good illustration of actual poisoning is given by Rusby [a] where out of a flock of 1,000 sheep which escaped into a laurel area, at least 27 showed symptoms of poisoning. Those affected were mainly the young ones. In these cases the tracks on the snow around the bushes and the presence of leaves in the stomach showed conclusively the cause of the trouble. Halsted [b] reported poisoning in cows after eating laurel wreaths which had been thrown from a cemetery into their pasture. A striking case occurred in the National Zoological Park, Washington, D. C., where six Angora goats were poisoned by laurel thrown to them by visitors; later, a Diana monkey died with typical symptoms after eating the leaves held to it by a visitor. The leaves of the plant were found in the monkey's stomach. The post-mortem examination in this case was negative. Since these poisonings occurred visitors have been prohibited from carrying laurel into the park.

Barton in 1802 [c] called attention to the fact that the honey made from *Kalmia angustifolia* was poisonous to man, and while no direct proof [d] has been published that honey made from *K. latifolia* is poisonous it is perfectly logical to suppose that it is, as Plugge found that honey made from *Rhododendron ponticum*,[e] a closely related plant, gave the same chemical and physiological tests on frogs and mice which he considers characteristic of its active principle, andromedotoxin. *Rhododendron ponticum* is the plant which is supposed to have yielded the honey which poisoned Xenophon's [f] army.

Under these circumstances the Secretary of Agriculture advised against raising bees in the neighborhood of mountain laurel. An unpublished report is on file at this office of investigations in which extracts of mountain laurel were mixed with honey and fed to bees.

[a] Rusby, H. H. The Poisonous Properties of Mountain Laurel. Drug. Cir. and Chem. Gaz., vol. 46, p. 27, 1902.

[b] Halsted, B. D. Eighth Annual Report of the New Jersey Agricultural College Experiment Station for 1895, p. 355, 1896.

[c] Barton, B. S. Some Account of the Poisonous and Injurious Honey of North America. Amer. Phil. Soc. Trans., 1802, vol. 5, p. 59.

[d] American Bee Journal, 1896, pp. 92, 146, 246, 262.—Root, A. I. A B C of Bee Culture, p. 249.—Honey from Mountain Laurel. American Bee Journal, vol. 35, p. 825, 1895.

[e] Plugge, P. C. Giftiger Honig von Rhododendron ponticum. Arch. d. Pharm., vol. 229, p. 554, 1891.—Thresh, J. C. Notes on Trebizonde Honey. Pharm. Jour. and Trans., 1887–88, vol. 18, pp. 397, 404.

[f] Pliny. Nat. Hist. (Translated by Bostock and Riley), vol. 4, p. 341.—Abbott, K. E. Letter, in Proc. Zoolog. Soc. London, pt. 2, p. 50, 1834.

The name of the investigator can not now be ascertained. These bees are said to have shown no symptoms, but the honey they made produced typical symptoms in two persons who ate it.[a] It has been claimed that the flesh of birds after eating laurel is poisonous to man,[b] but Wilson,[c] Audubon,[d] and Aaron[e] state that they have frequently eaten without injury partridges whose craws were filled with laurel leaves and buds. It is probable that many of these cases of poisoning were really due to ptomaines, as they usually occurred from undrawn animals.

There are few cases in man of poisoning with laurel. Children are said to have been poisoned by eating the plant in mistake for *Gaultheria procumbens*,[f] although there are no published cases to that effect. Laurel is claimed to be used in certain liquors to render them more intoxicating.[g] Barton[h] noted that the flowers of *Kalmia latifolia* would produce a vesicular eruption in certain persons.

EFFECT OF MOUNTAIN LAUREL ON SHEEP.

Stable-fed sheep and lambs were turned into an inclosed area in which the mountain laurel was the only green plant. These sheep, which were kept under observation for several hours, refused to do more than merely nibble at the leaves, and when placed in grassy areas where this plant was growing they positively refused to touch it. These observations agree with those of Wood[i] on *Kalmia angustifolia*. Other animals besides sheep seem disinclined to eat it. Kalm reported in 1754 that the leaves of the trees in Pennsylvania were devoured by a worm, but that the mountain laurel leaves were untouched.[j]

Sheep weighing about 50 pounds (25 kilos) were fed with doses of 5, 10, 15, 25, and 35 grams of the dried ground-up leaves inclosed in gelatine capsules without producing poisonous symptoms. Fifty grams, when given to a sheep weighing 33.5 kilos, induced a staggering gait and slight salivation, but doses of 85 grams would cause death in a very few hours unless diarrhea set in. Under these

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[a] Unpublished answer to inquiry. See note on page 35.

[b] Barton, B. S., l. c., p. 60.—Elliot, D. G. "Game Birds" of the United States. Report of the Commissioner of Agriculture for 1864, pp. 363, 364, 1865.

[c] Wilson, A., and Bonaparte, C. L. Amer. Ornithology, vol. 2, p. 319, Edinburgh, 1831.

[d] Audubon, J. J. Birds of America, vol. 5, p. 79, 1871.

[e] Aaron, C. E. Cram's Magazine, vol. 2, p. 502, 1900.

[f] Unpublished correspondence. (G. Watkins, 1896.)

[g] Chesnut, V. K. Principal Poisonous Plants of United States. U. S. Dept. Agr., Div. Bot. Bul. 20, p. 45.

[h] Barton, B. S. Collections for an Essay Towards a Materia Medica of the United States, p. 35, 1804.

[i] Wood, T. F. Is Sheep Laurel Poisonous to Sheep? American Agriculturist, vol. 42, p. 66, 1883.

[j] Kalm, P., l. c., vol. 1, p. 266.

conditions sheep have survived this dose. In starved animals no doubt smaller doses would be poisonous.

One experiment was with a sheep about 7 years old; weight about 22.5 kilos. On June 1, 1905, at 11:05 a. m., the temperature[a] was 104.5° F., respiration 60, pulse 90 per minute. A slight secretion from the nostrils was present owing to a coryza; pupils about one-fourth of an inch wide; the conjunctival, buccal, and mucous membranes normal. Eighty-five grams of powdered dried laurel leaves in sealed gelatine capsules were given. The feeding lasted twenty-five minutes.

Following the administration of the capsules little inclination to eat was manifested, urination and slight defecation taking place during the first hour. At 1 p. m., respiration was 110 per minute, pulse 117, temperature 104° F. Marked disinclination to move was shown, the sheep permitting itself to be easily turned on its side. It ate only sparingly. Two hours after taking the laurel leaves urination was repeated and slight emesis set in, followed soon by mental dullness, as shown by decreased attention to surrounding objects, with a loss of alertness, while the face took on a sleepy appearance and saliva began to accumulate about the mouth. Respiration was somewhat labored and the unsteadiness in gait became marked. Two and three-fourths hours after eating the laurel the sheep assumed an awkward attitude in standing, the hind legs being set wide apart. Repeated emesis became a prominent feature and continued for about an hour, the ejecta being thin and mustard-like. Apparently to facilitate breathing, the mouth was kept open most of the time. Weakness and unsteadiness increased until three and one-fourth hours after eating the laurel. At this time it was difficult for the animal to stand.

At 2:46 p. m. the temperature was 107° F., respiration 50 per minute, pulse 124. The pupils were of the same size as before the feeding. The abundant nasal secretion at this time became a very marked symptom, and continued so throughout the history of the case. Weakness increased until the animal could not stand, and a diminished sensitiveness to skin irritation was noted. Death ensued quickly at 3:06 p. m. No convulsions were noted at any time.

The post-mortem examination was made at once. The sheep appeared to be well nourished. Some mustard-colored ejecta were found in the trachea as well as in the bronchioles. The lungs crepitated markedly, but showed no special amount of fluid. The pleural cavity contained no increased amount of fluid. The mucous membranes were not discolored. The heart contained no clots, was not dilated, and contained only a little dark blood. The stomach was full of food and its walls showed no signs of irritation. The intestines

[a] In all cases the temperature was taken by the rectum.

were apparently congested, but showed no hemorrhages. The small intestines were more or less filled with thin normal-looking contents. The kidneys appeared normal, the bile was of a dark-green color, and the bladder was contracted and empty. The central nervous system was not examined.

The bile from this sheep, which amounted to about 20 c. c., was treated with alcohol, and after evaporating off the alcohol in vacuo was precipitated with lead acetate. The filtrate when freed from lead by H_2S and injected into guinea pigs produced absolutely no symptoms characteristic of laurel poisoning.

On May 22, 1905, one of the yearlings previously used, weighing 24.5 kilos (49 pounds), was fed with 90 grams of powdered dried laurel leaves in sealed gelatine capsules, the feeding beginning at 11:15 a. m. and taking about fifteen minutes. Before feeding, the pulse was 135, respiration 50 per minute, rectal temperature 103.9° F. After forty-five minutes an increased secretion of saliva became evident about the mouth and the sheep nibbled slightly at the grass. At 1:15 p. m. the temperature was 105° F., the head was held low, respiration was somewhat labored, and saliva ran profusely from the mouth; pulse 104, respiration irregular, 144 per minute, pupils unchanged. Two and a quarter hours after feeding, the animal became less active, the ears were held back, and the general aspect was that of a sheep half asleep. Respiratory and salivary symptoms continued, the animal standing with the hind legs wide apart and showing evidence of weakness in the hind quarters by a staggering gait.

Four hours after feeding, profuse nasal secretion became a conspicuous feature and weakness increased to such a degree that the subject was unable to stand; respiration 120, temperature 104° F. The nostrils were moist; pupils normal. Convulsions soon appeared, with sensitiveness to touch persisting in the conjunctiva; knee jerks active, pupils a trifle dilated. Ten minutes later emesis followed. Respiration was apparently increasingly difficult. The hind legs seemed stiff. At 3:50 p. m. the pulse was 104 per minute, temperature 103.8° F., with continued attempts at emesis and repeated tossing of the head from side to side; pupils normal. Death ensued at 9:30 p. m.

No discoloration of the mucous membranes was noted, and constipation prevailed during the period of observation. At no time was a marked thirst shown. The post-mortem examination made the following day showed the trachea injected and very moist and two or three teaspoonfuls of pure serum in the pleural cavity. The lungs were œdematous. The auricles were relaxed and filled with black clots; the left ventricle contained very little black blood, while the right ventricle contained very much more. The abdomen was distended with gas. The stomach was partially filled with food; the second and third stomach walls showed no special lesions, but

the intestines throughout showed marked hemorrhagic enteritis. The small intestines contained very little solid matter, but there was some well-formed fecal matter in the cœcum. The liver was perhaps a trifle pale and the kidneys were slightly injected. The spleen showed no macroscopic change. In none of these cases was it possible to secure the urine for examination, as the bladder was found empty.

On October 14, 1905, a five-year-old (?) sheep, having a temperature of 101.8°F., at 1:20 p. m. was given 90 grams of fresh laurel leaves ground up and mixed with meal. The ration was practically all eaten at 3:20 p. m., when the temperature stood at 104° F. At 6 o'clock on the next morning a failure of appetite, together with slobbering, was noted. Numerous soft stools were found in the pen during the day. At 10:12 a. m. increased salivary secretion produced a frothy appearance about the mouth and the sheep held its head low. At 2:15 p. m. slight emesis and marked secretion of nasal mucus occurred accompanied by a temperature of 103.5° F. Twenty-five hours later the slobbering had ceased, but the appetite had not returned and the temperature stood at 102.9° F. Twenty-two hours later (1:45 p. m., October 17) the temperature was 103.5° F. and the animal seemed normal. The presence in the pen of numerous soft stools was noted. The sheep recovered.

EFFECT OF MOUNTAIN LAUREL ON RABBITS.

On February 6, 1905, a rabbit weighing 2,096 grams received hypodermically one drop of aqueous extract of laurel (1 gram of dried leaves in 3.75 c. c. of water). Further administrations were made as follows: February 13, 2 drops; February 21, 3 drops; February 25, 4 drops; February 28, 6 drops; March 3, 9 drops; March 7, 12 drops; March 10, 14 drops; March 22, 20 drops. On the last date evidence of laurel action appeared and a slight loss of appetite was noted. On March 30, 25 drops were administered as before, followed on April 5 by 30 drops. At this time the animal weighed 1,828.5 grams. At 9:49 a. m. the temperature was 100.9° F., the administration of the extract following three minutes later. The resulting events were as follows: 10:05 a. m., mouth moist; 10:50 a. m., convulsions; 11:15 a. m., could not stand; 11:55 a. m., could sit up in usual posture; 1:54 p. m., appeared normal. At 3:50 p. m. the temperature was 103.3° F. The animal lived about a year after the close of this investigation.

A rabbit weighing 1,559 grams, which had not received any previous injections, was given hypodermically at 9:54 a m., April 5, 1905, 30 drops of the extract used in the preceding case. The temperature five minutes before administration was 100.8° F. The following symptoms developed rapidly: After nine minutes, interfer-

ence with the gait, followed shortly by urination and increasing evidences of weakness, with marked difficulty in standing, was noted; slight convulsions were seen 35 minutes after administration, repeated at intervals during the following hour and a quarter; at 11:15 a. m. paralysis of the hind legs led to a straddling attitude, head held back, and sphincter relaxed. The temperature at 11:50 a. m. was 95.2° F. At 1:54 p. m. the animal was much better. It could walk but staggered. At 3:49 p. m. the temperature was 102.3° F.; condition good. The rabbit seemed apparently all right until April 13, when convulsions occurred which were followed by death.

GENERAL SYMPTOMS OF POISONING.

The symptoms commonly observed are salivation, tearing, an increased flow of secretion from the nose, emesis with convulsions, and later paralysis of the limbs. On post-mortem examination the main macroscopic lesion is dilation of the vessels of the intestinal walls,[a] and if the case is not too acute, hemorrhages into the intestinal walls occur, resembling what is known as rhododendron poisoning. The aqueous extract of the flowers produced the same symptoms on rabbits as that made from the leaves.

ACTIVE PRINCIPLE.

Comparatively little chemical work has been done with mountain laurel save testing for a volatile oil [b] and arbutin.[c] Most of the chemical work has been done on a closely related plant, *Andromeda japonica*, now known as *Pieris japonica*. Eykmann [d] isolated an amorphous glucosidal body which he called asebotoxin, which melted at 120° C. and had a lethal dose for rabbits of 3 mg. per kilo. Plugge [e] studied the same plant, making his first report in 1882. He extracted the plant with water, then precipitated with lead acetate and lead subacetate, and after removing the lead with sulphureted hydrogen or sodium sulphate concentrated the fluid in vacuo at 50° C. This colorless fluid was then shaken out with chloroform, and the chloroform on evaporation left transparent, noncrystalline scales, which he called andromedotoxin. The mother liquid gave an amorphous

[a] In one case of poisoning by *Andromeda polifolia*, this was noted by Plugge. Ueber d. Vorkommen d. Andromedotoxins in Andromeda Polifolia. Arch. d. Pharm., vol. 221, p. 814, 1883.

[b] Stabler R. H. On Kalmia Latifolia. Amer. Jour. Pharm., n. s., vol. 10, p. 246.—Bullock, C. On Kalmia Latifolia. Amer. Jour. Pharm., n. s., vol. 14, p. 260, 1848.

[c] Kennedy, G. W. Arbutin in Kalmia Latifolia. Amer. Jour. Pharm., vol. 47, p. 5, 1875.

[d] Eykmann, I. F. Sur le Principe Toxique de l'Andromeda Japonica. Rec. d. Travaux Chim. des Pays-Bas, vol. 1, p. 224, 1882. Phytochem. Notizen u. einige japan. Pflanzen. Abhandl. d. Tokio Daigaku, No. 10, p. 1, 1883.

[e] Plugge, P. C. Ueber Andromedotoxin. Arch. d. Pharm., vol. 221, p. 1, 1883.

body, andromedorübrin. This andromedotoxin gave no precipitates with alkaloidal reagents and did not reduce Fehling's solution, but gave certain color reactions and produced distinct and characteristic symptoms on injection into guinea pigs and frogs—severe retching, which, however, is absent after large doses; disturbances of respiration; convulsions, and paralysis.

The characteristic color reactions are as follows:

(1) Concentrated sulphuric acid gives a dark reddish brown color and dissolves it gradually. On warming it becomes a deeper red. On dilution with water this passes into a light mulberry-red, disappearing with alkalis returning with H_2SO_4.

(2) Evaporation with dilute H_2SO_4 (1:5) on water bath causes rose-red color. If the body is pure there is no odor, but if not pure there is an odor of ericinol, due to the decomposition of ericolin, an attached body.

(3) Dilute HCl acts the same as H_2SO_2, only it gives a color more nearly violet-red.

(4) Dilute phosphoric acid, 25 per cent, gives a mulberry-red color. By this means 0.0000005 gram of andromedotoxin can be recognized.

Especial emphasis is laid on the second and fourth reactions.[a] Plugge also extended his studies to other members of this group. The first of these to be examined was *Andromeda polifolia*. He made the plausible claim that because the chloroform "shaking" from the aqueous extract freed from extraneous matter by lead gave the same color reactions and produced the same action in animals as that from *Pieris japonica* it contained the same active principle, but he admitted that this body was much less active than the andromedotoxin obtained from *Pieris japonica*. He explained this weakness as being due to the fact that the plant was grown on a different soil and that the active principle varied from that of *Pieris japonica* much as the active principle of the various species of Digitalis and Aconitum vary.[b]

In using this method with *Leucothoë catesbaei*[c] Plugge noted that the first six or seven chloroform shakings gave an amorphous residue, while the seventh to the ninth gave a white crystalline body from which he obtained the characteristic physiological action and color reactions of andromedotoxin.

From *Chamaedaphne calyculata* he obtained some crystalline deposit, but in this case from the lack of material was unable to

[a] Plugge, P. C. Vorkommen von Andromedotoxin in verschied. Ericaceen. Arch. d. Pharm., vol. 223, p. 906, 1885.

[b] Plugge, P. C. Ueber d. Vorkommen d. Andromedotoxin in Andromeda Polifolia. Arch. d. Pharm., vol. 221, p. 818, 1883.

[c] Plugge, P. C. Vorkommen von Andromedotoxin in verschied. Ericaceen. Arch. d. Pharm., vol. 223, p. 905, 1885.

positively identify it as crystalline andromedotoxin. The material obtained from this plant was less active physiologically than that obtained from *Pieris japonica*. Crystals were also obtained from *Azalea indica*.

In 1887 Plugge[a] and his pupil de Zaayer[b] made a more extended study of the andromedotoxin obtained from *Rhododendron ponticum*. They summed up the previous chemical work and studied the active principle pharmacologically. They claimed that the body shaken out by the chloroform could be precipitated from alcohol or chloroform solution by ether in the form of crystalline needles. Muto failed to obtain these needles from *Pieris japonica*, the plant Plugge first worked with. This body contained carbon, hydrogen, and oxygen, but no nitrogen, and melted at 228° to 229° C. Plugge and de Zaayer gave it the empirical formula $C_{31}H_{51}O_{10}$, although the figures for this conclusion were not exact. It was readily soluble in water and alcohol, but very slightly in ether. They stated that it was more soluble in cold than in hot water, although Plugge elsewhere states the opposite. In water, alcohol, and amyl alcohol it turns the plane of polarization to the left, while dissolved in chloroform it turns it to the right. It gives no precipitate with alkaloidal reagents. When subcutaneously injected, 0.0001 gram caused death in a frog (*Rana temporaria*) in a few hours.

This conjoint paper apparently so settled the question as to indicate that all that was necessary to determine the presence of andromedotoxin was to ascertain if the chloroform shaking from the plants gave the same physiological action and the same color reaction as that described for andromedotoxin. Plugge did this with *Kalmia latifolia* and from its action on frogs decided that the fluid extract contained one-half of 1 per cent of andromedotoxin. By this method he decided that andromedotoxin was present in the following plants:

Pieris japonica Thunb.
Andromeda polifolia L.
Leucothoë catesbaei (Walt.) Gray.
Chamaedaphne calyculata (L.) Moench.
Rhododendron grande Wight.
Rhododendron barbatum Wall.
Rhododendron fulgens Hook. f.
Rhododendron cinnabarinum Hook. f.
Rhododendron puniceum Roxb.
Rhododendron ponticum L.
Rhododendron chrysanthum L.
Rhododendron hybridum Ker.
Rhododendron falkoneri Hook. f.
Rhododendron maximum L.
Kalmia latifolia L.
Kalmia angustifolia L.
Azalea indica L.
Monotropa uniflora L.
Pieris formosa Don.
Pieris ovalifolia Don.

[a] Plugge, P. C. Ueber Andromedotoxin. Arch. d. Pharm., vol. 221, p. 12, 1883.

[b] Zaayer, H. G. de. Untersuch. ü. Andromedotoxin. Arch. f. gesam. Physiol., vol. 40, p. 480, 1887.—Plugge, P. C. Andromedotoxin. Verhandl. d. X internat. med. Cong., vol. 2, pt. 4, p. 28, 1891.

Plugge concluded that andromedotoxin was the active principle of the Ericaceæ in general.

In the case of *Rhododendron hirsutum*, Plugge[a] found that the chloroform shaking failed to produce any immediate symptoms in frogs, but three hours after injection convulsions with slight respiratory disturbance occurred, with the secretion of mucus from the mouth. These symptoms completely disappeared, differing from those of andromedotoxin. This extract gave no reactions with dilute or concentrated HCl, 25 per cent phosphoric acid, and dilute H_2SO_4. In studying the distribution of andromedotoxin, Plugge makes the interesting observation that concentrated solutions of *Erica vulgaris*, now known as *Calluna vulgaris*, injected subcutaneously into frogs cause symptoms resembling those of andromedotoxin poisoning, yet chemically no trace of this body could be found.[b]

Lasché also studied the action of extracts of *Kalmia latifolia* and *K. angustifolia* on animals, and corroborated Plugge's data, but isolated no pure body and made no chemical analysis. He used the berries in his work.[c]

Matusow,[d] while accepting the belief that andromedotoxin is the active principle of the leaves, says that the chemical reactions of the root correspond with those of andromedotoxin, except with hydrochloric acid. He claims the presence of calcium, magnesium, aluminum, manganese, and iron in the roots.

Archangelsky[e] examined another member of the Ericaceæ, the *Rhododendron chrysanthum*, a native of Siberia, and isolated a crystalline principle, rhododendrin, with the empirical formula $C_{16}H_{22}O_7$, which was inactive to frogs, and a crystalline body, rhododendrol, which acted on frogs similarly to camphor. He also claimed the presence of andromedotoxin, but did not isolate it. He examined *Rhododendron ponticum* and obtained the same color reactions and physiological reactions found by Plugge with andromedotoxin.

[a] Plugge, P. C. Andromedotoxinhaltige Ericaceen. Arch. d. Pharm., vol. 229, p. 553, 1891.

[b] Plugge, P. C. Fortgesetzte Untersuch. ü. d. Verbreit. d. Andromedotoxins in d. Familie d. Ericaceen. Arch. d. Pharm., vol. 27, p. 171, 1889.

[c] Lasché, A. J. M. Examination of Some of the Poisonous Ericaceæ of North America. Pharm. Rund., vol. 7, p. 208, 1889.

[d] Matusow, H. Analysis of the Root of Kalmia Latifolia. Amer. Jour. Pharm., vol. 69, p. 341, 1897.

[e] Archangelsky, K. Ueber Rhododendrol, Rhododendrin und Andromedotoxin. Arch. f. exper. Path. u. Pharm., vol. 46, p. 313, 1901.

Hayashi and Muto failed to obtain crystalline andromedotoxin from *Pieris japonica* by using Plugge's method.[a]

So it can not be said that the active principle from mountain laurel has been actually isolated in a pure state. Using Plugge's method, the writer failed to obtain active crystals from mountain laurel, but obtained crystals by a different method, namely, from the filtrate after ether precipitation. Plugge's principle is precipitated by ether. In no case has the writer found the ether precipitate physiologically active, and an ether extract of the crude plants possessed the toxic action of the plant. Full details as to the chemical and pharmacological investigations will be made later.

Laboratory animals, as guinea pigs and rabbits, after subcutaneous injection show tearing, retching, convulsions, and later paralysis. This physiological reaction can be used as a guide in the isolation of the active principle. Before death in males there is an ejection of semen.

REMEDIAL AGENTS.

The fact that sheep which have diarrhea have recovered from toxic doses of mountain laurel would suggest purgative treatment. Farmers very commonly administer lard in this condition, and this no doubt acts by hindering absorption. The use of lard in laurel poisoning has been substantiated by the experiments of Thomas, who found that the animals were less likely to become poisoned if lard was administered. In case vomiting and purgation do not occur, this result should be encouraged by the usual agents.[b] To induce vomiting, 60 milligrams of apomorphine hydrochlorate may be given subcutaneously and purgation may be encouraged by giving 2 to 6 ounces (60 to 180 grams) of epsom salts dissolved in water as a drench. The treatment is purely symptomatic and no true antidote is known.

It seems of interest to ascertain whether the action on the glandular secretion noted can not be obtained free from great toxicity by a change in the chemical structure of the active principle.

MEDICINAL ACTION.

Thomas treated one case of diarrhea by means of a decoction of *Kalmia latifolia*, and the leaves have also been used empirically in the treatment of certain stages of fever. Locally an ointment has

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[a] Hayashi, H., and Muto, K. Ueber Athmenversuche mit einigen Giften. Arch. f. exper. Path. u. Pharm., vol. 47, p. 220, 1902.

[b] Remarkable Instance of the Absence of Animal Instinct. Penny Magazine, vol. 7, p. 283, 1838.

been employed for various forms of skin diseases, such as tinea, etc., but now it has fallen entirely out of use. A tincture is still used by homeopathic physicians.[a] The only indications for its use would be as a substitute for some member of the veratrine or aconitine family.

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[a] Boericke and Tafel. Amer. Homeop. Pharm., 1896, p. 279.

NOTE.—*Kalmia angustifolia* is used by the Cree Indians as a tonic. Bul. Torrey Bot. Club, vol. 12, p. 53, 1885.

NOTE TO THE SECOND EDITION.—Since the publication of this article it has been learned that the leaves used by the experimenter referred to on page 26, footnote *a*, were examined by Prof. Victor K. Chesnut, whose card catalogue was found very useful in preparing the historical portion of this paper, and he identified them as those of oleander and not of mountain laurel.

121—II

B. P. I.—340.

RESULTS OF LOCO-WEED INVESTIGATIONS IN THE FIELD.[a]

By C. DWIGHT MARSH, *Expert, Poisonous-Plant Investigations.*

FIELD WORK.

The word "loco," from the Spanish, meaning crazy, has been applied for a great many years to a disease of stock and sheep in the semiarid region of the West. There has been a general belief among stockmen that the disease is caused by certain weeds known as loco weeds. The name loco weed has been applied to a large number of plants, but two are considered especially obnoxious—*Aragallus lamberti* and *Astragalus mollissimus.*

More or less desultory investigations by scientific men have been made on this subject, the general result of which has been to imply that the disease was produced by some other cause than the loco plants. The later investigations have made it seem quite probable that the cause of the disease must be sought in some other direction. The investigations here recorded were undertaken to clear up first of all the doubt concerning the source of trouble.

The first essential point was to demonstrate whether the loco weeds did or did not cause the disease. The work of the first season, the summer of 1905, accomplished this demonstration in a very satisfactory way. It was clearly proved that *Aragallus lamberti* would

[a] For many years stockmen of the plains east of the Rocky Mountains have reported great losses due to a somewhat undefined cause known as "loco." It has been estimated that the losses from this source in Colorado alone have reached the sum of a million dollars per annum. A thorough investigation of the loco problem by the Bureau of Plant Industry, both in its field and laboratory aspects, was undertaken by the office of Poisonous-Plant Investigations, under the direction of Dr. Rodney H. True, Physiologist in Charge, the field work being in the hands of Dr. C. Dwight Marsh, Expert, and the laboratory work in those of Dr. Albert C. Crawford, Pharmacologist.

The importance of the results obtained, together with the fact that the publication of the rather extensive evidence accumulated is likely to be somewhat delayed, has made it seem desirable to present at once a brief summary of the results obtained.—B. T. GALLOWAY, *Chief of Bureau.*

poison horses, sheep, and cattle and that *Astragalus mollissimus* would poison horses. *Astragalus mollissimus* does not poison cattle because they very rarely eat it.

The work of the second season, the summer of 1906, was mainly devoted to a diagnosis of the disease. The external symptoms described by stockmen were in general corroborated. The principal symptoms are the lowered head, rough coat, slow, staggering gait, movements showing lack of muscular coordination, sometimes more or less paralytic symptoms, a generally diseased nervous system, and in the later stages of the disease extreme emaciation.

The principal pathological changes are pronounced anemia of the whole system, diseased stomach walls, and in acute cases a congested condition of the walls of the stomach, while in chronic cases there are frequently ulcers. Generally speaking, locoed cattle have ulcers in the fourth stomach. There is an excess of fluids in the various cavities of the body. This is especially noticeable in the epidural space of the spinal canal. Here the effusion is more or less organized, presenting the appearance of a gelatinous mass, which is especially abundant in the lumbar region and about the exits of the spinal nerves. In most locoed females the ovaries are found in a diseased condition.

The third stage of the work was the devising of remedial measures. This was undertaken in the summer of 1907. This work naturally had two phases, (1) attempts to eradicate the weed and (2) attempts to cure the locoed animals.

In regard to the possibility of killing the weeds, it was found that this could readily be done in the case of fenced pastures. This is especially feasible with *Astragalus mollissimus*, because it occurs in comparatively small patches. *Aragallus lamberti* has a wider distribution, but it is not at all impossible to destroy this weed when in pastures. There seems to be no way of ridding the ranges of these weeds, however.

In regard to the second phase of remedial work, it was found that locoed cattle can in most cases be cured by a course of treatment with strychnine, while locoed horses can generally be cured by a course of treatment with Fowler's solution. The animals under treatment must not be allowed to eat the loco weed and should be given not only nutritious food but, so far as possible, food with laxative properties. To this end magnesium sulphate was administered to correct the constipation which is almost universal among locoed animals. It should be noted, too, that magnesium sulphate may serve to some extent as an antidote to the poison.

It may be added, in regard to the question of immunity, that loco poisoning comes on in a slow and cumulative manner, so that there is no possibility of animals becoming immune.

LABORATORY WORK ON LOCO-WEED INVESTIGATIONS.

By ALBERT C. CRAWFORD, *Pharmacologist, Poisonous-Plant Investigations.*

SUMMARY OF LABORATORY WORK.

(1) Conditions analogous to those found in locoed animals occur in portions of the world other than the United States, especially in Australia.

(2) The symptoms described in stock on the range can be reproduced in rabbits by feeding extracts of certain loco plants. Those especially referred to here under the term "loco plants" are *Astragalus mollissimus* and *Aragallus lamberti.*

(3) The production of chronic symptoms in rabbits is a crucial test of the pharmacological activity of these plants.

(4) It is the inorganic constituents, especially barium, which are responsible for this poisonous action, at least in the plants collected at Hugo, Colo.; but perhaps in future loco plants from other portions of the country may be found to have other poisonous principles.

(5) There is a close analogy between the clinical symptoms and pathological findings in barium poisoning and those resulting from feeding extracts of certain of these plants. Small doses of barium salts may be administered to rabbits without apparent effect, but suddenly acute symptoms set in analogous to those reported on the ranges.

(6) The administration of sulphates, especially epsom salts, to form insoluble barium sulphate would be the chemical antidote which would logically be inferred from the laboratory work, but of necessity these sulphates would have to be frequently administered, and their value after histological changes in the organs have occurred remains to be settled. But the treatment of acute cases of barium poisoning in man is not always successful, even when sulphates combined with symptomatic treatment are employed. The conditions under which sulphates fail to precipitate barium must be considered.

(7) Loco plants grown on certain soils are inactive pharmacologically and contain no barium. In drying certain loco plants the

barium apparently is rendered insoluble, so that it is not extracted by water, but can be extracted by digestion with the digestive ferments. To be poisonous the barium must be in such a form that it can be absorbed by the gastro-intestinal tract.

(8) In deciding whether plants are poisonous it is desirable to test not merely the aqueous or alcoholic extract, but also the extracts obtained by digesting these plants with the ferments which occur in the gastro-intestinal tract.

(9) It is important that the ash of plants, especially of those grown on uncultivated soil, as on our unirrigated plains, be examined for various metals, methods similar to those by which rocks are now analyzed by the United States Geological Survey being used.

(10) It is desirable to study various obscure chronic conditions, such as lathyrism, with reference to the inorganic constituents of the Lathyrus and other families of plants.

121—III

B. P. I.—341.

THE SOURCES OF ARSENIC IN CERTAIN SAMPLES OF DRIED HOPS.[a]

By W. W. STOCKBERGER, *Expert, Drug-Plant Investigations.*

INTRODUCTION.

For several years considerable attention has been given in England to the question of the origin of the arsenic sometimes found there in beer.[b] Some students of the question have pointed out glucose,[c] malt,[d] and hops[e] as possible sources of this substance. The occasional detection of minute quantities of arsenic in dried hops has furthered the belief that hops should be carefully examined for traces of this undesirable substance, a view which finds partial support in some experiments made with hops dried by each of the two processes used in England.[f] In one of these, known as the "direct" process, the hops are dried over open fires and are thus exposed to all the combustion products arising therefrom. In the other, or "indirect" process, a current of pure heated air is caused to pass through the

[a] The growing and curing of hops has been a subject of investigation in the Bureau of Plant Industry during the past two years by the office of Drug-Plant Investigations, under the direction of Dr. Rodney H. True, Physiologist in Charge. The execution of the work in both field and laboratory has been chiefly in the hands of Dr. W. W. Stockberger, Expert. In connection with these investigations, that phase concerning the occurrence of arsenic in hops has been touched upon with fruitful results, which are here summarized. Since the conclusions reached have an important bearing on matters of considerable economic importance, their immediate publication is deemed desirable.—B. T. GALLOWAY, *Chief of Bureau.*

[b] Royal Commission on Arsenical Poisoning, London, 1901–1903. Report of the Medical Officer of Health for the City of London, No. 86.

[c] Windisch, W. Wochenschr. f. Brauerei, vol. 18, p. 30, 1901.—Häntke, E. Letters on Brewing, vol. 1, pp. 16–21, 1901.—Petermann, A. Ann. Sci. Agron., vol. 2, p. 396, 1901.

[d] Chapman, A. C. Analyst, vol. 26, p. 10, 1901.—Fairley, T. Analyst, vol. 26, p. 177, 1901; Pharm. Jour., vol. 65, pp. 634, 738, 1900.

[e] Baker, J. L., and Dick, W. D. Jour. Soc. Chem. Ind., vol. 23, p. 174, 1904.

[f] Duncan, C. County Analyst's Annual Report to the Worcestershire County Council, 1905, Appendix I, pp. 22–24.

hops, which do not come into direct contact with the gases or fumes from the fires. From the experiments cited the conclusion is drawn that hops dried by the indirect process are arsenic free.[a]

It is known, however, that traces of arsenic sometimes occur in hops which have been dried by the indirect process, a condition which has been urged in England as an argument against the purchase of imported hops, thus rendering more difficult the sale abroad of those grown in the United States.

Since under the ordinary conditions of hop production in the United States there is a surplus which requires an annual exportation of a considerable portion of the crop,[b] it is highly desirable that this product be prepared in every way free from deleterious substances which would interfere with its sale and use abroad.

During a recent study of the processes of curing and sulphuring hops[c] some experiments were made to determine the most probable source of arsenical contamination. The possible sources include fuels, arsenical sprays, the soil, and sulphur both when used in the field to destroy pests and when burned under the hops on the kiln during the drying process.

Since the open-fire, or "direct," process of drying is never used in this country, and as traces of arsenic have been found in hops not treated with insecticides, only the soil and sulphur were considered in these experiments, which, though not fully complete, have yielded results of so much importance to American hop growers that they are here presented in preliminary form.

ORIGIN OF SAMPLES OF HOPS EXAMINED.

The geographical distribution of hops containing traces of arsenic was first investigated. Dry commercial samples were obtained from England, Belgium, East Prussia (Altmark), Bavaria, Bohemia (Saaz), British Columbia, New York, Wisconsin, and the Pacific coast. Upon analysis[d] small quantities of arsenic (1.5 parts to the million, or less) were detected in samples from each of the regions just mentioned. These results indicate that hops from any of the hop-growing districts of the world may contain traces of arsenic, and suggest the necessity for the thorough examination of hops whatever

[a] Duncan, C., loc. cit., p. 24.

[b] Merritt, E. Bul. 50, Bureau of Statistics, U. S. Dept. Agriculture, table 5, p. 13.

[c] Stockberger, W. W. Farmers' Bulletin No. 304, U. S. Dept. Agriculture, 1907, pp. 19–26.

[d] Except when otherwise stated all analyses for arsenic were made in the Bureau of Chemistry, United States Department of Agriculture.

their geographical origin, as well as the desirability of a careful scrutiny of the methods of cultivation and curing used abroad, particularly those processes in which, contrary to the American practice, hops are dried over open fires.

EXAMINATION OF HOP SOILS.

Samples of soil from a number of American hop fields have been examined for arsenic,[a] but in no case has its presence been detected. However, these results do not necessarily prove the absence of arsenic from the soils of the fields examined, since the hop plant has a very extensive and deep-growing root system which might very readily explore soil layers unrepresented in the samples taken.

Since traces of arsenic have been found in unsulphured hops grown on some of the soils from which these samples were taken, it may be inferred that the samples were not representative of the true soil conditions as just noted or that arsenic may be present in the soil in quantities too minute to be detected by the ordinary methods of analysis, the larger and measurable quantity in the plant being due to gradual accumulation during the process of growth.

THE ABSORPTION OF ARSENIC BY THE GROWING PLANT.

Some early authors held that living plants did not absorb arsenic,[b] but numerous plants have been found to contain this substance,[c] which was doubtless derived from the soil. Nobbe[d] states that only a very small quantity of arsenic is taken up by plants, though according to Angell[e] plants of rhubarb, bean, rye, and buckwheat accumulate appreciable quantities from soils heavily fertilized with superphosphates. Davy[f] found arsenic in peas, cabbages, and Swedish turnips grown in soils mixed with superphosphates, 40 per cent of which Lyttkins[g] states contain arsenic, in amounts varying from 0.012 to 0.26 per cent as estimated by Stoklasa.[h] Collins[i] found that barley

[a] The analysis of the soil samples was made in the Bureau of Soils, United States Department of Agriculture.

[b] Targioni-Tazzetti, A. Ann. Sci. Nat., ser. 3, vol. 5, pp. 177–191, 1846.—Dauberry, Chas. Quart. Jour. Chem. Soc., vol. 14, pp. 209–230, 1862.

[c] Pfeffer, W. Pflanzenphysiologie, 2 ed., vol. 1, pp. 432–433, 1897.

[d] Nobbe, F., Baessler, P., and Will, H. Landw. Versuchstat., vol. 30, p. 409, 1884.

[e] Angell, A. and A. F. Chem. and Drug., vol. 60, p. 430, 1902.

[f] Davy, E. W. Philos. Magazine, vol. 18, pp. 108–113, 1859.

[g] Lyttkins, A. Kgl. Landw. Akad. Handl., vol. 33, pp. 317–320, 1894.

[h] Stoklasa, J. Ztschr. Landw. Versuch. Oesterr., vol. 1, p. 154, 1898.

[i] Collins, S. H. Jour. Soc. Chem. Ind., vol. 21, pp. 222–223, 1902.

grown on soils containing arsenic may accumulate large amounts of this element, most of which, as has been further shown by pot experiments,[a] occurs in the barley grains. Likewise, Gosio [b] records the accumulation of arsenic in the leaves, stems, and fruits of squash plants which had been watered with dilute arsenic solutions.

In order to test the capability of the hop plant to take up arsenic from the soil, two adjoining plats of sixty hills each were selected in a hop yard and from May 24 to August 5, 1907, the alternate hills of one plat were watered weekly with solutions of arsenious acid and those of the other with solutions of arsenic acid. Each solution was made up in five different strengths, the arsenious acid ranging from 0.01 to 1 per cent and the arsenic acid from 1 to 3 per cent. Solutions of each acid were then applied to fifteen groups of two hills each in amounts so regulated as to form a gradually increasing series. In this way the total amount of arsenious acid administered to the plants of each hill ranged from one-tenth of an ounce to 24 ounces and the arsenic acid from 2 to 20 ounces to each hill. When the hops were mature, those from each group of two hills which had received the same treatment were gathered separately, dried without sulphur, and prepared for chemical examination.

Upon analysis traces of arsenic, from 0.5 to 3 parts per million, were found in each sample examined. While the amount of arsenic in various samples was not in direct proportion to the amount administered to the plant, the balance of evidence is in that direction. Necessarily the experimental error is very large, but when due allowance is made for it the results warrant the conclusion that hops will take up from soils containing available arsenic amounts relatively proportional to the quantity contained therein.

IMPURE SULPHUR AS A SOURCE OF ARSENIC.

That the sulphur used in sulphuring hops frequently contains small quantities of arsenic is quite generally known and has been suggested as the source of the arsenic occasionally found in dried hops.[c] However, analysis of the different grades of sulphur in common use indicates that from the quantities applied in most cases sufficient arsenic would not be produced to account for the traces sometimes found in hops, provided it was uniformly distributed through them. Analysis shows that there is often wide variation in the amount of arsenic contained in samples drawn from different bales

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[a] County Councils Cumberland, etc. Tech. Education Rept., vol. 10, pp. 1–121, 125–150, 1901.

[b] Gosio, B. Atti r. Accad. Lincei, vol. 15, pp. 730–731, 1906; abstract in Centbl. Bak. Par. u. Infek., part 2, vol. 18, pp. 724–725, 1907.

[c] Rüffer, E. Wochenschr. f. Brauerei, vol. 18, p. 109, 1901.

of the same lot in which all the hops were grown and dried under practically the same conditions, and also in samples drawn from different portions of one and the same bale.

This apparent contradiction may be explained on the assumption that the arsenic volatilized by the burning of the sulphur is deposited on the layers of hops next the floor of the kiln while the upper layers remain practically free. To test this theory, a series of experiments was made with a small kiln in which different lots of hops were separately exposed to the fumes of equal amounts of the different grades of sulphur, after which samples were carefully taken from the top and bottom layers before the hops were removed. The experiment was repeated with double the quantity of each grade of sulphur used before. For comparison, a certain quantity of arsenious oxid was added to the sulphur, with which a final lot was treated.

The preliminary results of these experiments fully support the theory that arsenic may be transferred from sulphur to hops and unequally distributed therein. The analysis of the samples shows in practically every case a very appreciable difference between the amounts of arsenic deposited in the upper and lower layers of the hops. The evidence further indicates that the greater portion of the arsenic is deposited in the bottom layer. The variation in the results obtained with the different grades of sulphur was less than was anticipated, since each grade apparently increased materially the arsenic content of the hops.

Although each test was repeated, using double the amount of sulphur, the relative proportion of arsenic present was not constant. However, the results indicate that a larger arsenic content may be expected when the proportion of sulphur used is increased.

The samples from the last experiment, in which arsenious oxid (the white arsenic of commerce) was added to the sulphur, contained relatively large quantities of arsenic, twelve times as much being found in the hops of the bottom layer as in those of the top layer.

CONCLUSIONS.

From the foregoing experiments the following conclusions are drawn:

(1) Traces of arsenic may occasionally be found in dried hops irrespective of their geographical origin.

(2) If available arsenic is present in the soil it may be taken up by the hop plant under favorable conditions.

(3) Except in rare cases the amount of arsenic derived from the soil by the hop plant is probably smaller than 0.01 grain per pound of dry hops, which is the smallest amount regarded as deleterious by the Royal Commission on Arsenical Poisoning in England.

(4) By the use of impure sulphur during the process of curing, hops may be contaminated with arsenic, which will be concentrated in the lower layers on the kiln floor with the result that certain samples may show an amount greater than 0.01 grain per pound.

(5) The probability of hops acquiring arsenic from what seems to be a very ready source may be much lessened by employing only the very highest grades of purified sulphur in hop curing, and the quantity used should be reduced to the lowest possible limit.

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B. P. I.—342.

APPLE LEAF-SPOT CAUSED BY SPHAEROPSIS MALORUM.

By W. M. Scott, *Pathologist*, and James B. Rorer, *Assistant Pathologist*, *Investigations of Diseases of Fruits.*

INTRODUCTION.

The disease of apple leaves known as "brown-spot," "frog-eye," "leaf-blight," or "leaf-spot" is very common throughout the eastern United States. As these names suggest, the disease is characterized by circular or irregular reddish brown spots with slightly raised purplish margins. (Pl. III, fig. 1.) These spots when first visible to the naked eye are very minute and purple, but rapidly increase in size until they attain a diameter of from one-eighth to one-half inch, while the affected tissue becomes brown and later sometimes gray. The mature spots are usually circular, but after midsummer may become more or less irregular or distinctly lobed in outline, a condition apparently brought about by a secondary extension of the disease from two or more points on the margin of the original circular spot. If the infection is bad, a number of spots may coalesce and form large brown patches involving half the leaf or more, but in these dead areas the margins of the individual spots usually remain distinct.

These spots should not be confused with those produced on apple leaves by the apple-blotch Phyllosticta. The latter are yellowish and minute, never more than one-sixteenth of an inch in diameter, and will not be considered in this paper.

Leaf-spot is of greater economic importance than is generally supposed. It makes its first appearance early in the spring as the leaves are unfolding, and infections take place continuously throughout the growing season. As a result of its attacks trees may become completely defoliated from six weeks to two months before the normal period of leaf fall. If this is repeated for a series of years, the trees become weakened and the life of the whole orchard is materially shortened. Moreover, the fruit from such prematurely defoliated

trees is small and of poor quality, and the fruit buds must necessarily go into the dormant stage in a rather immature condition, often resulting in a partial or complete failure of the next year's crop.

CAUSE OF LEAF-SPOT.

Considerable confusion has existed as to the cause of this leaf-spot disease. Though no inoculation experiments have been reported, the disease has generally been conceded to be of fungous origin and has commonly been attributed to *Phyllosticta pirina* Sacc., and less commonly to *Phyllosticta limitata* Pk. and *Sphaeropsis malorum* Pk., while species of Hendersonia, Pestalozzia, and other fungi have been reported as occurring on the diseased areas.

The disease in its economic aspect was first mentioned by Alwood [1] [a] in 1892, when he described a "brown-spot" of apple foliage and reported a serious outbreak in the Virginia orchards during the preceding summer. He attributed the trouble doubtfully to *Phyllosticta pirina.*

In 1895 Kinney [2] cited the same fungus as the cause of apple and pear leaf-spots in Rhode Island.

Stewart,[3] in 1896, reported a serious outbreak of leaf-spot on Long Island caused by an undescribed fungus which Peck named *Phyllosticta limitata.*

In 1898 Alwood [4] again recorded the common occurrence of *Phyllosticta pirina* on leaf spots, but found *Sphaeropsis malorum* Pk. and *Hendersonia mali* Thüm. associated with it.

Lamson,[5] in 1899, gave *Phyllosticta pirina* as the cause of "brown-spot" of apple foliage in New Hampshire, while Corbett,[6] in 1900, described a "brown-spot," or "frog-eye," in West Virginia due to the same fungus.

In 1902 Stewart and Eustace [7] questioned the parasitism of *Phyllosticta pirina* and *P. limitata.* In their opinion "at least a large part of the so-called apple leaf-spot is due to spray injury and weather conditions and not to fungous origin." They suggest that the fungi in question live saprophytically on leaves injured by Bordeaux mixture and arsenical sprays, or in the case of unsprayed trees on leaf-spots which are in some way the result of atmospheric influences. A possible explanation for the formation of the spots is "when a shower is followed by bright sunshine, drops of water on the leaves act as lenses and concentrate the sun's rays to such an extent as to overheat the tissues underneath."

In 1902 Clinton [8] recorded *Sphaeropsis malorum* as the cause of brownish spots on apple leaves in Illinois "much like those of the

[a] The serial numbers used in this paper refer to the bibliography, which will be found on page 54.

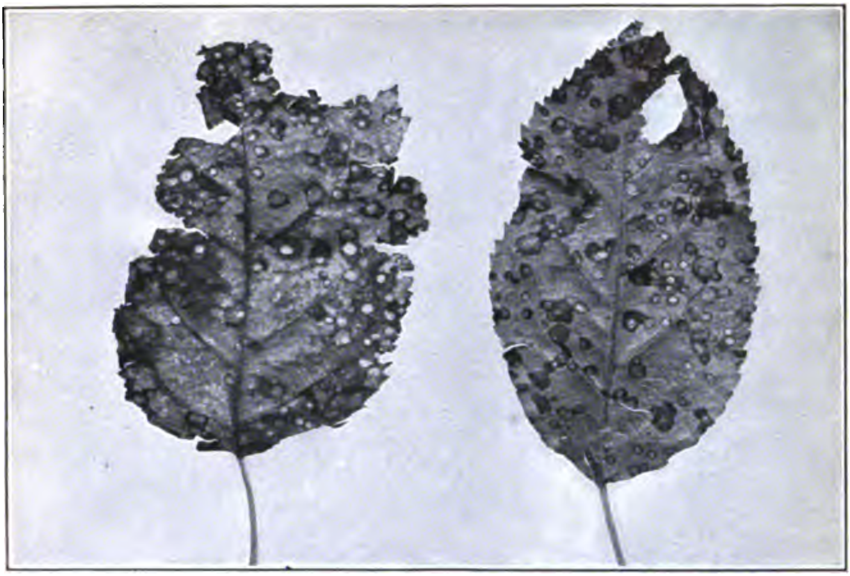

FIG. 1.—APPLE LEAVES SHOWING LEAF-SPOTS PRODUCED BY NATURAL INFECTION.

FIG. 2.—APPLE LEAVES SHOWING LEAF-SPOTS PRODUCED BY INOCULATION WITH SPHAEROPSIS MALORUM, PK.

leaf-spots or Phyllostictae fungi, but are apt to be more irregular and larger." The same author,[9] in 1903, stated that most of the apple leaf-spot troubles in Connecticut were due to this same fungus.

Stone and Smith,[10] 1903, in accounting for a serious outbreak which occurred in Massachusetts the previous year say "there can be no reasonable doubt that frost was the destructive agency." They observed that the spotting of the leaves continued throughout the summer, and that even as late as August spots as a result of spring frost developed on leaves which had not previously shown the injury.

Sheldon,[11] in 1907, transferred the fungus *Phyllosticta pirina* Sacc. to the genus Coniothyrium on account of the dark color of the spores and proposed the name *Coniothyrium pirina* (Sacc.) Sheldon. From an examination of herbarium material and fresh specimens from different parts of the eastern United States there is no doubt that the fungus commonly called *Phyllosticta pirina* in this country is a Coniothyrium. Apparently mature spores from a European specimen of *Phyllosticta pirina* in the herbarium of the Department of Agriculture are hyaline and ellipsoid, agreeing with the original description of Saccardo,[12] so that his species may prove to be autonomous.

In view of the conflicting statements and apparent uncertainty as to the cause of apple leaf-spot, the writers during the summer of 1906 and 1907 made a study of the disease in connection with demonstration spraying work in the Ozarks. It was found that *Sphaeropsis malorum*, contrary to the general belief, is the cause of the disease.

CULTURAL STUDIES.

A somewhat cursory examination of a large amount of leaf-spot material collected in Arkansas during 1906 showed that there was no one fungus which fruited constantly on the spots. The pycnidia of *Coniothyrium pirina* (Sacc.) Sheldon were found perhaps more commonly than any other, but two species of Pestalozzia and one each of Coryneum, Hendersonia, and Alternaria occurred frequently, while occasionally the pycnidia of *Sphaeropsis malorum* and a species of Septoria were met with. The same was true of specimens received from Missouri, Nebraska, New York, Maryland, Virginia, and West Virginia. Pure cultures of all of these fungi were easily obtained by the poured-plate method. All grew well and fruited abundantly on apple agar or sterilized apple wood.

In the early part of the season of 1907 cultures were obtained from leaf spots by a somewhat different method. During the first spring outbreak of the disease, spots of various sizes, together with a little of the surrounding healthy tissue, were cut from the leaf and placed in a solution of mercuric chlorid (1–1,000) for two or three minutes. The bits of leaf were then thoroughly washed in sterile water and

transferred to slanted apple or potato agar. The writers separately made many sets of cultures by this method, using spots from leaves of Ben Davis, Winesap, and White Pearmain trees. Within a few days by the aid of a hand lens hyphæ could be seen growing out from the center or margins of the small spots. Mycelium developed rapidly and in about two weeks spores were formed, so that the fungi could be identified. The results were uniformly the same. In all cases in which the youngest spots, that is, those one-sixteenth of an inch or less in diameter, were used, the fungous growth was a pure culture of *Sphaeropsis malorum* Pk. In cultures made from the older spots, in which the central tissue had become brown, sometimes a pure Sphaeropsis was obtained, but more often a mixture of things. *Coniothyrium pirina* developed about as commonly as Sphaeropsis, both species often growing from the same spot. In addition to these two fungi, two species of Alternaria, a Cladosporium, bacteria, and yeasts were frequently present.

This cultural work, frequently repeated, gave evidence that *Sphaeropsis malorum*, always developing from the youngest spots, was the specific cause of the disease and that the other organisms were mere concomitants. Of course, to prove this inoculation experiments were necessary. These were made as soon as pure fruiting cultures of the different fungi were obtained.

INOCULATION EXPERIMENTS.

A number of different sets of inoculations were made, but the method of procedure was the same in each case. With a sterile needle the fruiting fungus was scraped from the surface of the agar and transferred to a tube of sterile water. In cases where pycnidia were present these were crushed against the side of the tube with a sterile glass rod to set free the spores. In order to ascertain the presence of mature spores a hanging drop of the fluid was always examined microscopically. This spore-bearing liquid was then sprayed on both surfaces of clean young leaves with an atomizer. Trees in more or less isolated young orchards were selected, and no two fungi were used on the same tree. From 20 to 40 leaves on two or three different shoots were involved in each inoculation. Checks were always made on separate trees by spraying 40 or 50 leaves with sterile water.

The first inoculations were made on May 28, 1907. The fungi used were *Sphaeropsis malorum*, and the undetermined species of Coryneum, Hendersonia, and Alternaria previously mentioned. It was raining at the time and the weather continued wet for several days.

On June 3, 1907, purple specks were appearing on the leaves which had been inoculated with Sphaeropsis, and on June 18 these leaves were badly affected with leaf-spot. (Pl. III, fig. 2.) On a twig bearing 30 leaves, 12 showed a dozen or more well-developed spots, and a few of these leaves had from 80 to 90 spots each. Twelve other leaves on the same branch had from 2 to 10 spots each, while only 6 remained free from the disease. On another branch 12 out of 20 leaves were badly affected.

With the exception of an occasional spot, evidently resulting from natural infection, the leaves sprayed with spores of the other fungi, as well as those sprayed with sterile water as a check, remained free from the disease.

Another experiment was made on June 19, 1907. Spores of *Sphaeropsis malorum*, *Coniothyrium pirina*, Coryneum, and Alternaria were used. The work was done at sunset following a shower, so that the leaves were wet. Again the leaves inoculated with the spores of *Sphaeropsis malorum* soon became badly affected with the characteristic leaf-spot disease, while the others, including the checks, developed no more than an occasional spot.

Another test was made with Sphaeropsis alone. The young leaves of a 2-year-old tree were inoculated during a period of dry weather in mid-June. The spores were sprayed on the leaves at about 10 o'clock, while the sun was shining brightly. At the same time sterile water was sprayed on the leaves of an adjacent tree as a check.

Though no rain fell for at least six days after the spraying was done, numerous purple specks began to appear on the inoculated leaves within a week and soon developed into the characteristic brown spots. A few spots, never more than one to a leaf, appeared on the checks. The mature spores of Sphaeropsis germinate so rapidly that in dry weather the dews provide sufficient moisture for leaf infection, as indicated by this experiment.

Inoculations made on June 26, 1907, with *Sphaeropsis malorum*, Coryneum, and Alternaria gave results similar to those previously recorded for these fungi. From 20 to 50 spots developed on each of the leaves inoculated with Sphaeropsis, while only a few scattered spots occurred on the leaves of the check and on those sprayed with spores of the other fungi.

On August 4, 1907, inoculations with Coniothyrium were again tried. Leaves on rapidly growing 2-year-old Ben Davis trees in a nursery were used. The spores were obtained from a fresh culture and were so numerous that they clouded the liquid. The work was done during a light shower and some rain fell the next day.

The same experiment was repeated on the evening of August 14, 1907. Though it did not rain at this time the trees were wet down with sterile water on the following night.

Again, on August 21, 1907, this same fungus was used for inoculations, which were made in the evening just after a heavy rain. For the next two days the sky was overcast and occasional showers fell.

The results of these three sets of inoculations with Coniothyrium were negative. Spots were found here and there on the inoculated leaves, but no more than on the checks which were sprayed with sterile water. Similar spots, never more than two to a leaf, were found throughout the nursery at this time and were evidently produced by a natural infection with Sphaeropsis.

CONCLUSIONS.

The following conclusions may be drawn from the results of the inoculation experiments described in the preceding pages:

Sphaeropsis malorum Pk., the black-rot fungus, is parasitic on apple leaves, producing circular (or irregular) reddish brown spots an eighth of an inch or more in diameter, and is undoubtedly the cause of the apple leaf-spot disease which occurs in the middle West. The common apple leaf-spot disease of the Eastern States, being so similar in every respect, is doubtless caused by the same fungus, although some other fungi may possibly produce similar spots.

Coniothyrium pirina (Sacc.) Sheldon, although it occurs abundantly on apple leaf-spots, appears to have nothing to do with their formation.

The several other fungi that were tested, such as *Hendersonia* sp., *Coryneum* sp., *Pestalozzia* sp., and *Alternaria* sp., proved to be non-parasitic in these experiments and probably occur on leaf spots only as saprophytes.

SOURCE OF INFECTION.

Sphaeropsis malorum is perhaps the most common fungus that inhabits pome-fruit orchards east of the Rocky Mountains. It is the cause of the black-rot of the apple, the pear, and the quince and produces cankers on trunks and branches of these fruit trees. It occurs abundantly on dead twigs and branches in nearly every orchard, producing spores in enormous numbers. This is perhaps the most fertile source of infection for both fruit and foliage. In old orchards, particularly where pruning is neglected, the leaf-spot disease is much worse than in young orchards. The leaves of young trees adjacent to an old orchard become more spotted with the disease than those farther removed. Another source of infection is the diseased fruits of the previous year's crop. Although the fungus fruits only sparingly on leaves on the tree, it produces fertile pycnidia in considerable numbers on these leaves after they have fallen to the ground.

FIG. 1.—UNSPRAYED WINESAP TREES DEFOLIATED BY THE LEAF-SPOT DISEASE.

FIG. 2.—SPRAYED WINESAP TREES IN FULL FOLIAGE, LOCATED IN THE SAME ORCHARD AND PHOTOGRAPHED AT THE SAME TIME (OCTOBER 19, 1906) AS THOSE SHOWN IN FIGURE 1.

TREATMENT.

Since 1892, when Alwood[13] first recommended Bordeaux mixture as a preventive for apple leaf-spot, other writers have advocated the same method of treatment. The prevention of this disease has been one of the most striking results of various spraying experiments and demonstrations conducted by the Bureau of Plant Industry. Waite, in 1901, in connection with bitter-rot experiments in Virginia, controlled the disease with two applications of Bordeaux mixture. His recommendations in Farmers' Bulletin No. 243, p. 19, are based upon this work. Similar results were obtained by Scott[14] in Virginia in 1905. In the spraying demonstrations in the Ozarks during 1906 and 1907 the writers found that the spraying ordinarily necessary for the protection of the fruit from fungous attacks[a] will usually control this leaf trouble without any additional treatment. During both seasons unsprayed trees were shedding their leaves by August 1 and were completely defoliated by the middle of September, while the sprayed trees remained in full foliage until the first killing frost. (Compare Pl. IV, figs. 1 and 2.) In addition to the injurious effect upon the trees this premature defoliation caused the fruit to be small and of poor quality as compared with that from sprayed trees. An average barrel of Winesaps from sprayed trees contained 612 apples, while 731 from unsprayed trees in adjacent rows were required to fill a barrel.

For the control of this disease alone, without reference to the diseases of the fruit, an application of Bordeaux mixture should be made in the spring a week or ten days after the petals have fallen, a second application four weeks later, and a third about four weeks after the second. Three applications are necessary only in exceedingly wet seasons in sections where the disease is severe. Ordinarily two treatments, one about three weeks after the petals are off and the other four or five weeks later, are sufficient.

A weak Bordeaux mixture, such as 3 pounds of copper sulphate and 3 pounds of lime to 50 gallons of water, is effective in controlling this disease, Bordeaux mixture of full strength not being required.[b]

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[a] For a combination treatment for the leaf-spot disease, the diseases of the fruit, and the codling moth, see Farmers' Bulletin No. 283, pp. 41–42.

[b] For various formulas and methods of preparing Bordeaux mixture, see Farmers' Bulletin No. 243, pp. 5–10.

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B. P. I.—347.

THE IMMUNITY OF THE JAPANESE CHESTNUT TO THE BARK DISEASE.

By HAVEN METCALF, *Pathologist in Charge of the Laboratory of Forest Pathology.*

THE EXTENT OF THE BARK DISEASE.

The bark disease of the chestnut, caused by the fungus *Diaporthe parasitica* Murrill, has spread rapidly from Long Island, where it was first observed, and is now reported from Connecticut, Massachusetts, Vermont, New York as far north as Poughkeepsie, New Jersey, Pennsylvania, and possibly Delaware. It is no exaggeration to say that it is at present the most threatening forest-tree disease in America. Unless something now unforeseen occurs to check its spread, the complete destruction of the chestnut orchards and forests of the country, or at least of the Atlantic States, is only a question of a few years' time.

AN IMMUNE VARIETY.

Observations made by the writer during the past year indicate that all varieties and species of the genus Castanea are subject to the disease except the Japanese varieties (*Castanea crenata* Sieb. and Zucc.). All of the latter that have been observed in the field or tested by inoculations have been found immune. This fact can hardly fail to be of fundamental importance to the future of chestnut nut culture. Although the nuts are distinctly inferior in flavor to the European varieties, such as Paragon, the Japanese chestnut is already grown on a large scale as a nut-producing tree. There are, however, many trade varieties of dubious origin. Some of these may prove later to be subject to the disease. Immunity tests of all known varieties of chestnuts have been undertaken.

Attempts will also be made to hybridize the Japanese with American and European varieties, with the hope of combining the immunity of the former with the desirable qualities of the latter.

However excellent as a nut and ornamental tree, the value of the Japanese chestnut as a forest tree is doubtful. It can be recommended only experimentally at present for forest planting. It

certainly will not take the place of the American chestnut. The tree is said to attain a height of 50 or 60 feet in Japan. As seen in this country it is a handsome tree, dwarfish and compact in habit, and rather slow growing. It has hardly had time to show how large it can grow.

The immunity of the Japanese chestnut, together with the fact that it was first introduced and cultivated on Long Island and in the very locality from which the disease appears to have spread, suggests the interesting hypothesis that the disease was introduced from Japan. So far, however, no facts have been adduced to substantiate this view.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 121, PART I.

B. T. GALLOWAY, *Chief of Bureau.*

THE SUPPOSED RELATIONSHIP OF WHITE SNAKEROOT TO MILKSICKNESS, OR "TREMBLES."

BY

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THE SUPPOSED RELATIONSHIP OF WHITE SNAKE-ROOT TO MILKSICKNESS, OR "TREMBLES."[a]

HISTORICAL INTRODUCTION.

Many of the early settlers of the Ohio Valley, especially in Indiana and Illinois, were affected with a peculiar disorder known as milksickness, a disease which is said to have caused the death of Abraham Lincoln's mother. Persons with this disorder usually showed no mental disturbances save slight apathy, although late in the course of the disease there might be coma.

Milksickness was usually characterized by vomiting, which might be bloody, and obstinate constipation, but in rare cases this was absent.[b] So marked was this constipation that the name paralysis of the intestines was once suggested for the disorder.[c] The abdominal walls were retracted and the pulsations of the abdominal aorta could thus be easily seen. Later in the course of the disease tympanites has occurred.[d] The urinary secretion was diminished and the breath took on a peculiar fetid odor which was considered pathognomonic.

[a] One of the most serious diseases which formerly threatened the life of man and beast in the forested parts of the Ohio Valley and adjacent territory was that known as milksickness, or "trembles." Although of late years much less trouble has been experienced, an occasional outbreak is reported.

In responding to a request that the United States Department of Agriculture investigate an attack of milksickness occurring near Peoria, Ill., a favorable opportunity was obtained to test the widespread and persistent popular belief that the plant known as white snakeroot (*Eupatorium ageratoides* L. f.) is responsible for the trouble.

After a study extending through several months, Dr. Albert C. Crawford, Pharmacologist, acting under the direction of Dr. R. H. True, Physiologist in Charge of the Poisonous-Plant Investigations of this Bureau, has shown in the results summarized in this technical paper that the eating of the plant of the white snakeroot by animals or man is not followed by the disease and that there is probably no relation between them.—B. T. GALLOWAY, *Chief of Bureau.*

[b] Crookshank, N. On the "Sick Stomach" of the Western Country, or Gastro-enteritis. Phila. Jour. Med. and Phys. Sci., vol. 12, p. 254, 1826.

[c] Dawson, J. Causes and Treatment of Milksickness. Proc. Med. Convention, Ohio, 1842, p. 48.

[d] Wood, G. B. Treatise on the Practice of Medicine, vol. 1, p. 462, 1858.

Associated with these symptoms were those of prostration, with restlessness and great thirst. Pain was referred to various localities. The temperature usually remained normal or was subnormal, rarely exceeding 99° F.[a] At times it reached 100° F. There are, however, very few recorded cases in which the temperature was actually measured by a thermometer.[b] The pulse remained about normal, but might at times be accelerated. Nothing very characteristic was noted concerning the tongue save that it was enlarged.[c] In certain cases difficulty in swallowing was reported; in others hiccough was a more or less prominent symptom.[d] No reports were made as to the condition of the pupil or of any ocular disturbances save an intolerance of light.[e]

There was said to be an incubation period of from two to ten days,[f] although apparently some cases had no such period.[g] The disease itself usually lasted from two to twenty days, but chronic cases are reported.[h] The disorder generally occurred in spring or autumn, particularly in autumn, although it might appear at any season.[i] The conditions which were especially favorable for its development were said to be those which interfered with normal excretion.[j] One attack gave no immunity, but rather predisposed to a second one.[k]

The post-mortem records are few in number. The only lesions reported are those of irritation and inflammation of the stomach and

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[a] Kimmell, J. A. Milk Sickness in America. Verhandl. d. X internat. med. Cong., vol. 2, pt. 5, p. 54, 1891.

[b] Hurd, A. Milk Sickness. Clinic, Cincinnati, vol. 9, p. 280, 1875.—Way, J. H. Clinical History, Nature and Treatment of "Milk-Sickness." Amer. Jour. Med. Sci., n. s., vol. 106, p. 310, 1893.—Yandell, L. P. Inquiry into the Nature of the Disease Called Milk-Sickness. West. Jour. Med. and Surg., 3 s., vol. 9, p. 393, 1852.—Drake, D. Memoir on the Disease Called by the People "Trembles." West. Jour. Med. and Surg., vol. 3, p. 178, 1841.

[c] Graff, G. B. On the Milk Sickness of the West. Amer. Jour. Med. Sci., n. s., vol. 1, p. 354, 1841.

[d] Coleman, A. Observations on the Disease Generally Known by the Name of the Sick Stomach. Phila. Jour. Med. and Phys. Sci., vol. 4, p. 325, 1822.

[e] Graff, G. B., l. c., p. 354.

[f] Beach, W. M. Milk Sickness. Trans. Ohio State Med. Soc., vol. 38, pp. 131, 133, 1884.—Kimmel, J. A., l. c., p. 50.

[g] Yandell, L. P., l. c., p. 394.

[h] Yandell, L. P., l. c., p. 392.—Kimmell, J. A., l. c., p. 54.

[i] Byford, W. H. Milk Sickness. Nashville Jour. Med. and Surg., vol. 9, p. 467, 1855.—Yandell, L. P., l. c., p. 379.—Beck, J. C. Milk-Sickness. North-West. Med. and Surg. Jour., vol. 14, p. 497, 1857.

[j] Philips, W. H. Milk Sickness. Cincinnati Lancet and Observer, vol. 38, p. 142, 1877.

[k] Philips, W. H., l. c., p. 147.—Yandell, L. P., l. c., p. 392.

intestines,[a] as shown by hemorrhages into the lumen of these organs and injection of their walls, with at times adhesion of the intestinal walls to one another.[b] The pyloric region was found contracted,[c] and Peyer's and Brunner's glands were swollen. Graff has reported in one case adhesions and thickening of the cerebral membranes.[d] In other cases in which autopsies were made very slight lesions were noted.[e]

The clinical symptoms of some cases of milksickness resemble closely those described by Vaughan and Novy under the name galactotoxismus[f] and would probably be so diagnosed if they occurred outside of the areas where milksickness is prevalent. Schmidt[g] suggested that cases of milksickness occurred in cities, but were not diagnosed as such. Other cases resemble other forms of ptomaine poisoning described by Vaughan,[h] while the symptoms of still others resemble those occurring in Van Ermengem's cases of sausage poisoning. These cases described by Van Ermengem[i] showed marked nausea and vomiting and severe constipation, although two cases had diarrhea. There was retention of urine, while the temperature, pulse, and mental symptoms remained about normal, as in cases of milksickness. Some difficulty in swallowing was noted and there were ocular disturbances—diplopia, dilatation of the pupil, ptosis, etc. The post-mortem examination, as in milksickness, showed no char-

[a] De Bruler, J. P. Milk-Sickness. Chicago Med. Jour., vol. 15, p. 209, 1858.

[b] Davis, K. H. Milk-Sickness. Atlanta Med. Reg., vol. 1, p. 394, 1881–82.

[c] Byford, W. H., l. c., p. 465.—Drake, D. Morbid Anatomy of Milksickness. West. Jour. Med. and Surg., vol. 4, 1841, p. 234.

[d] Graff, G. B., l. c., p. 366.

[e] Crookshank, N., l. c., p. 256.

[f] Vaughan, V. C., and Novy, F. G. Cellular Toxins. 1902, p. 216. Compare Graff, G. B., l. c., p. 364; also Walker, J. W., Milk-Sickness. Science, vol. 8, p. 483, 1886.

[g] Schmidt, C. H. Milk Sickness. Cincinnati Lancet and Observer, vol. 20, p. 412, 1877.

[h] Vaughan, V. C. Ptomaïnes, Toxins and Leucomaïns. Twentieth Century Practice, vol. 13.

[i] Van Ermengem, E. Ueber einem neuen anaerob. Bacillus u. seine Beziehungen z. Botulismus. Zeits. f. Hygiene, vol. 26, p. 1, 1897; Untersuch. ü. Fälle v. Fleischvergift. mit Symptomen v. Botulismus. Cent. f. Bakter., part 1, vol. 19, p. 442, 1896.—Römer, P. Ein Beitrag z. Aetiologie des Botulismus. Cent. f. Bakter., part 1, vol. 27, p. 857, 1900.—Kempner, W., and Pollack, B. Wirkung des Botulismustoxins (Fleischgiftes) und seines specifischen Antitoxins auf die Nervenzellen. Deutsch. Med. Woch., vol. 23, p. 505, 1897.—Brieger and Kempner, W. Beitr. z. Lehre von der Fleischvergift. Deutsch. Med. Woch., 1897, p. 521.—Kempner, W. Weiterer Beitrag z. Lehre von den Fleischvergift. Das Antitoxin des Botulismus. Zeits. f. Hygiene, vol. 26, p. 481, 1897.—Osler, W. Modern Medicine, vol. 1, p. 232, 1907.

acteristic macroscopic lesion. From the spleen was isolated an anærobic bacillus which could reproduce the symptoms of the disorder in animals. This organism was found in various places in the meat used in making the sausage. On culture media it developed an odor of butyric acid. The toxin obtained from these cultures would resist heating at 70° C. for a short time, but heating to 100° C. destroyed it at once. Van Ermengem mentions that in cats injected with this toxin there was muscular rigidity and that the ocular symptoms in these animals were not marked. Dogs, however, were very resistant to the action of this toxin. This organism has also been found in the fæces of hogs. A similar outbreak occurred in Darmstadt after eating vegetables infected with the same organism.[a]

No doubt the term "milksickness" has been made to embrace a variety of clinical conditions; in fact, there has been such confusion in the reports that some authors, as Yandell, have denied its existence as a peculiar entity.[b]

The mortality as given by Coleman[c] is one death in every twenty or thirty cases. Others, as Mendenhall,[d] allude to milksickness as a "very grave disease"; others, again, speak of the outlook as favorable under the proper treatment.

In the same portions of the country in which milksickness occurred a similar, if not identical, disorder also affected domestic animals, especially cattle. In them muscular tremors were present and became especially noticeable when the animals were driven, so that this disorder received the name of "trembles."[e] It was also called the "tires," on account of the disinclination of the animals to move. A rigidity of the muscles has been noted by McCall.[f] The post-mortem examination showed the gastric mucosa to be softened and the stomach and intestines contracted,[g] in some cases gangrenous,[h] and at times there was more or less peritonitis. The odor developing at

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[a] Fischer, A. Ueber eine Massenerkrankung an Botulismus infolge Genusses "verdorbener" Bohnenkonserven. Zeits. f. klin. Med., vol. 59, p. 58. 1906.

NOTE.—The bacillus *Aerogenes capsulatus* which occurs in the human intestinal tract may give rise to infections associated with constipation. See Herter, C. A., Common Bacterial Infections of the Digestive Tract. 1907. p. 207.

[b] Yandell, L. P., l. c., p. 398.—Hibberd, J. F. Observations on Milk-Sickness. Western Lancet. 1845. vol. 3, p. 448.

[c] Coleman, A., l. c., p. 325.

[d] Mendenhall, I. Milk-Sickness. Chicago Med. Jour., vol. 18, p. 435. 1861.

[e] Yandell, L. P., l. c., p. 398.

[f] McCall, A. Facts and Observations on the Milk Sickness. West. Jour. Med. and Phys. Sci., vol. 3, p. 467. 1830.

[g] Graff, G. B., l. c., p. 362.

[h] Dickey, W. Essay on Milk Sickness. Western Lancet, vol. 13, pp. 391–395, 1852.

some of these autopsies was especially offensive and was compared with the odor arising in mercurialism.[a] In one case the cerebral ventricles contained fibrin and the brain itself was surrounded by serum and pus.[b] The spinal cord in this case showed signs of inflammation. In other cases no special lesions were noted.[c]

It was proved that many cases of milksickness were communicated to man by means of milk and its products[d] or meat[e] obtained from cattle affected with the "trembles"; even the amount of cream usually added to coffee is said to have induced the disease.[f] Other cases apparently arose without the products of diseased animals being eaten, as by using contaminated water;[g] and, again, cases have occurred in vegetarians.[h] In some cases the fencing off of the suspected springs from the pasture was followed by the disappearance of "trembles" from the neighborhood. The "trembles" still appear at times, although much less common than formerly,[i] its disappearance being traced to the cultivation of the soil;[j] and it is associated with certain shady, sharply localized, wet, untilled areas. No characteristic geological peculiarity has been proved for these areas.[k] Drake met the disorder almost entirely on oak plateaus, and especially on the so-called "slashes" or marshy areas.[l] It is claimed that the

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[a] Drake, D., l. c., p. 172.—McCall, A., l. c., p. 467.

[b] Graff, G. B., l. c., p. 363.

[c] Philips, W. H. Milksickness. Cincinnati Lancet and Observer, vol. 20, p. 132, 1887.—Beach, l. c., p. 137.

[d] Drake, D., l. c., p. 194.—Wilkinson, G. W. Etiology of Milksickness. Northwest. Med. and Surg. Jour., vol. 14, p. 156, 1857.—Townshend, N. S. Milk-Sickness. Jour. Comp. Med. and Surg., vol. 4, p. 118, 1883.—Schmidt, C. H. Milk Sickness. Cincinnati Lancet and Observer, vol. 20, p. 411, 1877.

[e] Yandell, L. P. Report on Milk Sickness. Proc. State Med. Soc. Kentucky, p. 94, 1868. [Gives negative reports.]

[f] Graff, G. B., l. c., p. 359.

[g] Crookshank, N. Observations on the Milk Sickness, Cincinnati, 1840, p. 11; Sick Stomack, Ohio Med. Rep., vol. 1, p. 11, 1826.—Yandell, L. P. Inquiry into the Nature of the Disease Called Milk-Sickness, West. Jour. Med. and Surg., 3 s., vol. 9, pp. 383, 389, 1852.—Walker, J. W. Milk-Sickness. Science, vol. 8, p. 483, 1886.—Wilkinson, G. W., l. c., p. 158.—Thompson, S. W. Milk-Sickness. West Jour. Med. and Surg., 3 s., vol. 11, p. 480, 1853.—Jones, J. T. Short Essay on Milk Sickness. East Tenn. Rec. Med. and Surg., vol. 1, p. 330, 1852–53.

[h] Jones, J. T., l. c., p. 329.

[i] Connor, J. J. Further Contribution to the Subject of Milk-Sickness. Chicago Clinic, vol. 17, p. 333, 1904.

[j] Yandell, L. P., l. c., p. 387.—Walker, J. W., l. c., 540; also Trans. Indiana State Med. Soc., 1873–75, p. 128.

NOTE.—Some areas are not entirely freed by cultivation.

[k] Yandell, L. P., l. c., p. 379.

NOTE.—J. S. Seaton in his "Treatise on the Cause of the Disease Called by the People the Milksickness," p. 10, claims that he can pick out milksick areas by the geological conditions.

[l] Drake, D., l. c., p. 184.

disease is contracted by leaving the cattle in these areas over night and that the disorder can be avoided by withdrawing them from pasture before dark.[a] Corn fodder experimentally exposed to the dew in these areas communicated the disorder to a yearling.[b]

One of the peculiarities claimed for this disease is that cows will show no symptoms so long as they are milked, while their nursing calves die with typical symptoms, but when the milking ceases the cows develop the symptoms in the usual manner. In other words, the poisonous agent is partially eliminated by the milk.[c] The urine is also claimed to eliminate a portion of the poisonous body.[d] The suspected milk in some cases was noted to be of a greenish color,[e] but usually there was no characteristic noted which is peculiar to it.[f]

The disease was apparently known to the early French missionaries in the eighteenth century, but accounts of it first appeared in medical literature in 1809–10.[g] They were numerous from 1840 to 1850, but now notices seldom appear.

The etiology of this disorder has remained in doubt, and Osler,[h] in an address before the young medical officers of the United States Army, mentions its causation as one of the many intricate problems remaining to be solved. Rewards were at one time offered by several States for the solution of this question, but these do not hold at present. Opinion has been divided as to whether "trembles," or milksickness, is of parasitic origin or due to the eating of certain plants, as *Rhus toxicodendron* or *R. venenata*,[i] *Bignonia capreolata*,

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[a] Beach, W. M. Milk-Sickness. Trans. Ohio State Med. Soc., vol. 38, pp. 128, 130, 1884.—Lea, W. W. Cursory Remarks on a Disease Vulgarly Called Milk Sick. Phila. Jour. Med. and Phys. Sci., vol. 2, p. 51, 1821.—Way, J. H., l. c., p. 312.

[b] Walker, J. W., l. c., p. 483.

[c] Kimmell, J. A., l. c., pp. 50, 52.—Drake, D., l. c., pp. 198, 200.—Graff, G. B., l. c., p. 360.

[d] Graff, G. B., l. c., p. 360.

[e] McCall, A. Facts and Observations on the Milk Sickness. West. Jour. Med. and Phys. Sci., vol. 3, p. 467, 1830.

[f] Graff, G. B., l. c., p. 359.

[g] Drake, D., l. c., p. 162; also West. Jour. Med. and Phys. Sci., vol. 3, p. 482, 1830.

[h] Osler, W. Aequanimitas, 1904, p. 116.

[i] Landrum, Z. C. Rhus Toxicodendron, the Cause of Milk Sickness. Atlanta Med. and Surg. Jour., vol. 7, A, p. 1, 1861.—Chase, S. C. Cause of Milk-sickness. Chicago Med. Jour., vol. 18, p. 438, 1861.—McIlhenny, J. J. Treatise on the Disease Called the Milk-Sickness, Springfield, 1843, p. 6.—Nichols, J. H. Milk-Sickness. Clinic, Cincinnati, vol. 10, p. 26, 1876.—Brewington, W. J. Milk-Sickness. Clinic, Cincinnati, vol. 10, p. 76, 1876.—Crook, J. W. Twenty Propositions on Milk-Sickness. North-West. Med. and Surg. Jour., vol. 14, p. 491, 1857.—Jones, J. T. Short Essay on Milk Sickness (*Colica trementia*). East Tenn. Rec. Med. and Surg., vol. 1, p. 324, 1852–53.

Eupatorium ageratoides, *Lobelia inflata*, etc.[a] Graff[b] eliminated arsenic, copper, etc., as causative factors and showed that small quantities of the butter or cheese (1 ounce) or of the beef (4 ounces) obtained from animals with the "trembles," if fed to a dog three times a day, would reproduce the symptoms in forty-eight hours and cause death in from three to six days; but his inoculations failed to produce the disorder. Graff adds that the poisonous principle seems to possess the power of infinite reproduction, stating, "It will be found that each pound of flesh of that animal so destroyed will possess as active powers of destruction, and will, in its turn, serve to contaminate the whole body of another animal in the same degree." Vermilya[c] claims that he was able to reproduce the disorder by feeding *Eupatorium ageratoides* and that his experiments were corroborated by Rowe, but A. W. Bitting, of Lafayette, Ind., reported to this Department his experiments in which he fed a horse 210 pounds (105 kilos) of this fresh green plant in five days without serious effect. He also fed two lambs with 80 pounds (40 kilos) without effect. Similar experiments are reported by Drake.[d] The theory of a plant poison was emphasized, as herbivorous animals were supposed to be the first affected and from them the disease transmitted to the carnivora, although the cases do not always originate in herbivora.[e]

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[a] Jerry, W. The Plant that Causes Milk Sickness. Med. and Surg. Rep., vol. 16, p. 270, 1867.—Drake, D., l. c., pp. 213–224.—Jones, J. T., l. c., p. 324.

[b] Graff, G. B., l. c., pp. 357, 360, 362.

NOTE.—Graff says the meat is active "raw or boiled," but there is evidently some mistake, as he states on page 361 that "I boiled a large quantity of the beef in pure water for several hours, and afterwards evaporated the liquid thus obtained to the consistence of cream. Although this extract contained a large quantity of gelatinous matter, with some of the other constituents of the flesh, yet, on being given in large quantities, no perceptible effect was produced."

Compton, J. W. Milk-Sickness. Indiana Med. Reporter, vol. 2, p. 255, 1881.

[c] Ohio State Board of Agriculture, 13th Ann. Rept. for 1858, 1859, p. 673.—Barbee, J. W. Facts Relative to the Endemic Disease Called by the People of the West Milk-Sickness. Western Jour. Med. and Surg., vol. 1, p. 182, 1840.—Drake, D., l. c., p. 214.

NOTE.—The view that arsenic is the etiological factor in milk-sickness has been strenuously upheld by Seaton in his Treatise on the Cause of the Disease Called by the People the Milksickness. Louisville, 1841.

[d] Drake, D., l. c., pp. 215–217.

NOTE.—The cases described by Barbee in the Western Journal of Medicine and Surgery, vol. 1, p. 182, 1840, in which dogs were killed with decoctions of this plant, seem to be merely cases of so-called salt action

[e] Compare Jones, J. T., l. c., p. 328.

In 1843 Heeringen,[a] and later, in 1853, Heusinger,[b] compared this disorder to anthrax, and in 1858 Wood on purely literary evidence argued the presence of "a germ."[c] Byford[d] and De Bruler[e] called attention to the fact "that it undergoes multiplication in the system" and that it lost none of its virulence by passing through four successive animals. Gardner[f] and Hessler[g] claim to have found parasites in the blood, while Philips[h] compares the organism seen by him to that met with in relapsing fever. The examinations of the blood made by Schmidt were negative.[i] Molds and mushrooms also have been claimed to be the etiological factors.[j] No one has yet reproduced the disease by injection of pure cultures of organisms.

The question thus remained in doubt, with the weight of evidence in favor of a parasitic origin, when a paper by Moseley[k] appeared. As his paper attributes the origin of this disorder to the eating of *Eupatorium ageratoides*, or white snakeroot, it was deemed advisable to analyze his evidence, as follows:

Experiment No. 1.—This consisted in feeding a cat weighing 4½ pounds (2,041 grams) with a solution made by extracting the leaves of three or four (?) plants in one pint (473 c. c.) of milk. After taking about one-half gill (59 c. c.) of this extract the animal showed tremors and dullness and was found dead in about twenty-six hours. The post-mortem examination proved to be negative. It is possible in this case that bacteria may have developed in the milk and produced poisonous compounds before feeding. This experiment was performed by Moseley's assistant and the animal was not seen by him until after death.

Experiment No. 2.—A tramp kitten of unknown history weighing 30 ounces (850.5 grams) was fed with a decoction made from one-half

[a] Heeringen, E. Discovery of the True Cause of the Disease Called by the People Trembles, or Milksickness, Louisville, 1843.

[b] Heusinger, C. F. Recherches de Path. Comp., vol. 1, p. 126, 1853.

[c] Wood, G. B., l. c., p. 465.

[d] Byford, W. H., l. c., p. 467.

[e] De Bruler, J. P., l. c., p. 209.

[f] Gardner, J. Milk-Sickness. St. Louis Med. and Surg. Jour., vol. 38, p. 290, 1880.

[g] Hessler, R. Preliminary Notes on an Almost Extinct Native Disease, Trembles or Milk-Sickness. Proc. Indiana Acad. Sci. for 1905, p. 122.

[h] Philips, W. H., l. c., p. 139.

[i] Schmidt, C. H., l. c., p. 412.

[j] Wilkinson, G. W., l. c., p. 159.—Howard, E. J. Mukosma. Indiana Jour. Med., vol. 2, p. 370, 1871.—Borland, S. Essay on the Milk Sickness, p. 27, Little Rock, 1845.—Drake, D., l. c., p. 218.—Johnson, J. M. Milk-Sickness. Atlanta Med. and Surg. Jour., vol. 7, B, p. 293, 1866. Compare also Mitchell, J. K., Five Essays.

[k] Moseley, E. L. The Cause of Trembles in Cattle, Sheep, and Horses and of Milksickness in People. Ohio Naturalist, vol. 6, pp. 463 and 477, 1906.

pound (226.8 grams) of the fresh plant and also some milk extract of the plant, more of the plant than the first (a larger cat) received. The cat was dull and showed tremors at times after the first feeding, but the appetite remained good, and eleven days later trembling could still be seen. Eighteen days later the animal was fed on the carcass of a rabbit which had died after eating the same plant (see experiment No. 6). This rabbit had died three days before the feeding of the cat began. Some tremors were seen in the cat, but it ate and continued active for three days, when it was killed. This experiment is open to the objection that nothing was known of the cat previous to the feeding, and cats often show slight tremulous movements of the cutaneous muscles. Then again, granting that the tremors were due to eating the meat, no record is made of having preserved the rabbit meat on ice, and decomposition may already have begun, and the mere presence of muscular tremors of unknown origin without the other clinical symptoms does not indicate the disease known as "trembles."

Experiment No. 3.—A cat whose previous history was not given was fed on the same carcass given to the cat referred to in experiment No. 2, and on that referred to in experiment No. 7, after it had stood two days, and the feeding was continued three days; then it was fed on a similar rabbit two days after death. This animal showed tremors and died in twenty days. The temperature of this animal rose about 2¼° F. on the third day before death. The buttocks were reported soiled, so evidently it had no marked constipation. Now, constipation is a symptom which Kimmell, Drake, Chesney, Graff, and others had previously noted in animals affected with the "trembles," and is one of the characteristics of milksickness.[a] Post-mortem examination showed two ounces of *acid* fluid in the peritoneal cavity.

Experiment No. 4.—A cat which was sick before beginning the experiment was fed with a milk extract of the plant, but only showed light symptoms (diarrhea) and "was seen to tremble only a few times and then under conditions which might probably have produced trembling without the aid of any poison." This animal was then fed on meat from one of the rabbits used in previous experiments. Moseley said that "the meat seemed to affect him more than the milk."

Experiment No. 5.—A dog was fed on an aqueous extract of the plant mixed with milk and some chopped-up plant mixed in hash and showed some trembling and weakness, but Moseley adds "he was not so different from usual except in the early morning but what all these things might have escaped notice if he had not been watched." In other words, an animal which Graff had shown to be very susceptible

[a] Chesney, J. P. Milk Sickness. St. Joseph Med. and Surg. Rep., vol. 1, p. 99, 1880.—Kimmell, J. A., l. c., p. 51.—Drake, D., l. c.; cow, p. 170; horse, p. 173; dog, p. 174.—Graff, G. B., l. c., p. 360.

to the "trembles," when fed with *Eupatorium ageratoides*, the supposed carrier of the disease, showed practically no symptoms. He then adds the remarkable report of his assistant: "While I held the dog's mouth open a friend poured the extract into the dog's mouth. The dog choked and coughed the extract into my face and mouth. I was in a room while the mixture was steeping and also on the previous evening. At 10.30 I was taken with a fit of cramps and the following day was nauseous. Several times during the three following days I had fits of trembling, always accompanying the extension of limb." In this connection it may be stated that the present writer's laboratory assistant and himself squeezed their material by hand, handled it, and made their own extracts in a rather close room without experiencing any such effects.

Experiment No. 6.—In this case 2 ounces (56.7 grams) of the snakeroot was placed in the cage with a rabbit. The rabbit died in three days. No tremors had been noted. This case can be excluded because of the absence of any accurate clinical report or histological examination, as rabbits are very apt to die of intercurrent diseases, especially coccidiosis.

Experiment No. 7.—This is of the same type as experiment No. 6, and open to the same objection. Moseley merely quotes the report of his pupil as to the presence of tremors.

Experiment No. 8.—This experiment consisted in injecting subcutaneously into a rabbit weighing 1,383 grams an aqueous extract of 3 grams of the plant. This injection was followed by tremors. Three days later the animal was fed with 2 to 3 ounces (57.7 to 85 grams) of the leaves and branches, and died in one hundred and twenty hours. There was no constipation. Moseley says, "The effects on her actions and appearance were not striking and might have escaped notice if I had not looked for them."

Experiment No. 9.—A rabbit was fed for three days with an aqueous extract of the plant. The only result noted was a "tremulous motion of the sides, with more rapid respiration." This animal was then fed with a milk extract of the plant. No constipation resulted, but the same trembling was seen, and save for a slight lessening of strength "she has seemed well."

Experiment No. 10.—This experiment consisted in feeding a milk extract of the plant, but with only slight action. A rabbit was reported to tremble after eating 67 grams of the leaves and branches of a fresh plant, but survived.

Experiment No. 11.—A young lamb weighing 40 pounds (18.14 kilos) was fed with the leaves of this plant. The animal showed trembling and died in four days, having eaten about 29 ounces (822 grams). There was no constipation. The kidneys were found to be

FLOWERING BRANCH OF WHITE SNAKEROOT (EUPATORIUM AGERATOIDES, L. F.).

much enlarged, weighing about twice as much as normal. One can form no positive opinion as to the cause of death. The enlarged kidneys, taken in connection with the history of convulsions and fluid in the peritoneal cavity, might suggest a nephritis.

Six ounces (170 grams) of the liver of this animal were fed to a cat. This cat showed merely a few tremors. A second cat also ate 6 ounces (170 grams) of the muscles but showed no tremors, and a dog after eating 4 ounces (103.4 grams) of the liver showed no symptoms save some dullness, but after feeding on the heart and spleen some tremors were noticed. None of these animals died.

These experiments, taken in the light of Graff's work, indicate that the sheep had not the disease commonly known as "trembles."

Moseley explains the lack of results in some of his experiments by the existence of a hypothetical immunity, but cases of milksickness are known not to possess immunity—in fact, one attack rather predisposes to another, so that it can not be said that Moseley has even proved *Eupatorium ageratoides* to be a poisonous plant, much less the cause of "trembles."

RECENT INVESTIGATIONS.

In the month of August, 1906, a rather serious outbreak of milksickness, or as it is frequently called in the case of stock "trembles," occurred in the vicinity of Minooka, Ill., resulting in the death of about 50 head of cattle. The office of Poisonous-Plant Investigations was asked to undertake an investigation into the cause of the trouble. In view of the fact that only plants as popularly understood are the subject of investigation by this office, only plants were studied. The widespread and popular belief that the eating of the white snakeroot (*Eupatorium ageratoides*), illustrated in Plate I, is the cause of the trouble seemed to direct the principal efforts of the investigations toward that common plant. It was found in considerable quantities in pastures in which the animals were supposed to have contracted the disease, and in a number of patches the plants had been browsed, presumably by the stock. Material from these patches, both dried and in chloroform water, was preserved for study.

EFFECT ON RABBITS.

EXTRACTS FROM DRY PLANT.

To prepare the material for use, 200 grams of the dry herb were extracted with cold water and the extract evaporated to the desired concentration in vacuo at about 55° C. When such an extract was fed to a rabbit weighing 4 pounds 2 ounces (1,871 grams) no symptoms were noted, either immediately or on the following day. Two days after the first dose a like quantity was again administered and no

symptoms appeared, the rabbit weighing 4 pounds 5 ounces (1,956 grams). After receiving three further doses, representing 200 grams each, in a period of five days the animal showed no symptoms of "trembles" or of suffering of any sort, the weight increasing under this treatment to 4 pounds 8 ounces (2,041 grams). The animal which had received this treatment gave normal delivery to young and made a rapid recovery, the young appearing abnormal in no respect. Thus, although the rabbit received the equivalent of 1,000 grams of the plant in a week, no symptoms of milksickness appeared and the animal steadily gained in weight.

After a rabbit weighing 4 pounds (1,814.3 grams) was injected subcutaneously in the back with an extract of 20 grams of the dried plant muscular tremors were felt in the limbs and in the masseter muscles, but recovery followed.

When a quantity of the same extract representing 40 grams was injected into a rabbit weighing 4 pounds 1 ounce (1,842.7 grams) no results followed, but an extract of 60 grams of the dried plant proved fatal in about twelve hours, the animal showing distinct tremors.

Following the injection of an aqueous extract representing 5 grams of the dried plant into a rabbit weighing 3 pounds 8 ounces (1,587.5 grams) there were no tremors and the rabbit was apparently normal, though the temperature rose 2.2 degrees F. in two hours and twenty-five minutes after the injection.

A rabbit weighing 3 pounds 12 ounces (1,700.8 grams) was injected subcutaneously with a concentrated extract representing 10 grams of dried Eupatorium and no tremors resulted, but in the two and one-half hours following the injection a fall of one-half a degree in the temperature was noted. Death followed during the night.

On increasing the quantity of extract until it represented 20 grams of the dried plant and injecting this subcutaneously, slight tremors were felt on careful examination by the hand over the hips after almost an hour and a half. An hour and forty minutes later no tremors were felt and the rabbit seemed normal. The temperature two and one-fourth hours after injection fell 2 degrees F. Death ensued during the night.

These animals had been kept under observation for two weeks preceding the experiment and had shown nothing abnormal.

EXTRACTS FROM FRESH PLANTS PRESERVED IN CHLOROFORM.

To prepare extracts from material preserved in chloroform the fresh plant was placed in a container and covered with water containing enough chloroform to prevent fermentation. When wanted for use the liquid was pressed out of the plant and concentrated in vacuo to the

proper degree. An extract representing 109 grams of the dried plant weighed after extraction (perhaps about 400 grams of the fresh plant) was given by mouth to a rabbit weighing 3 pounds 5 ounces (1,502.5 grams), but no symptoms were observed.

After a similar extract representing 127 grams of dry residue had been injected subcutaneously into the back of the same rabbit distinct tremors were shown in the hips and masseter muscles. Death followed during the night. No enlargement of the kidneys was seen.

EXTRACTS FROM ASH.

The method of preparation of extracts from ash was as follows: Ten grams of the dry herb were ashed in a platinum bowl and the ash washed into a porcelain bowl and carefully treated with acetic acid to decompose the carbonates, then evaporated to dryness and treated with water. The free acid was removed by repeated evaporation. The residue was treated with water, but not all dissolved, perhaps owing to the formation of basic salts. An emulsion consisting of the solution with the undissolved portion when injected subcutaneously produced marked tremors in the hips in rabbits after an hour and a quarter, and later in the masseter muscles. A marked acceleration of the respiration was also observed. After one and three-fourths hours the masseter muscles still twitched, but after two and one-fourth hours slight, if any, tremors were seen. No tremors were noted on the following day.

In ashing plants a large portion of the calcium-barium group will unite with the oxidized sulphur, forming insoluble sulphates, and thus be rendered inactive physiologically. Thus, trembling resulted from the injection of less of the inorganic salts than corresponds to 10 grams of the dry plant. This muscular twitching is well known to result from the hypodermic injection of certain salts (sodium, etc.), but not after administration by mouth.

An injection of a similar extract from 20 grams of the plant also produced the same result.

EFFECT ON CATS.

After an extract prepared from chloroform-preserved material corresponding to 50 grams of the dry plant residue was fed to a cat weighing 1 pound 8 ounces (680.3 grams), emesis followed in about fifteen minutes. When an aqueous extract corresponding to a dry plant residue of 39 grams was evaporated to 32 c. c. and 7 c. c. of this extract were fed twenty minutes after the emesis referred to and 11 c. c. were given thirty-five minutes later, urination and defecation followed promptly with renewed emesis in about ten minutes. Thirty

minutes after the administration of the last dose of extract 14 c. c. more were fed, emesis again resulting in about eight minutes, followed about fifteen minutes later by further efforts toward elimination by the intestines. Since in both dogs and cats emesis is especially easy, no especial significance is to be attached to that phase of the results. No tremors resulted and the appetite remained as usual.

In order to reduce the liability to emesis which may follow the administration of large doses, smaller quantities of the extract were given. If 7 c. c. of an extract concentrated to 32 c. c., representing a dried plant residue of 39 grams, were fed, no emesis followed for three hours. On taking a further dose of 8 c. c. the animal vomited within ten minutes. However, five minutes after this, slight movements of the skin could be seen, but these were apparently only such cutaneous movements as are commonly observed in cats. After 6 c. c. more were fed emesis soon followed. The same result followed the feeding of 11 c. c. after a period of about fifty minutes.

During the course of feeding with Eupatorium extracts as above indicated, the cat gained an ounce in weight in a week, showing normal appetite and evacuations. After four days more the weight increased about 5½ ounces (155.8 grams).

After a further interval of two weeks without treatment, when a concentrated extract representing 35 grams of plant was fed, no tremors or other abnormal symptoms were to be noted, although the animal was kept under careful observation. When, on the day following, an extract representing 65 grams was given no symptoms whatever followed other than evidence of a somewhat laxative action, and the cat continued to increase in weight. This animal gained 666 grams during the month it was kept under observation.

EFFECT ON DOGS.

An extract of Eupatorium representing 23 grams of the dried plant preserved in chloroform when fed to a dog kept under careful observation produced no symptoms, and the appetite remained normal; temperature before feeding, 100.6° F. When, twelve days later, a concentrated aqueous extract representing 200 grams of dried plant was given to the same dog, weighing 14 pounds 12 ounces (6,690.4 grams), having a temperature before feeding of 101° F., no symptoms resulted, the temperature after one and one-half hours registering 102° F. No symptoms appeared during observation for three more days, the weight increasing to 15 pounds 5½ ounces (6,959.8 grams). Eleven days later the weight increased to 16 pounds 15 ounces (7,682.7 grams). The animal was very playful throughout the investigation.

EFFECT ON SHEEP.

A lamb weighing about 25 kilos when fed 58 grams of the fresh plant showed merely some diarrheal symptoms.

EFFECT ON MAN.

The writer became so convinced of the harmlessness of the plant that he decided to take the plant extract himself. Four hundred grams of the fresh *Eupatorium ageratoides* were collected at Landover, Md., under the supervision of Prof. C. F. Wheeler, one of the botanists of the Department of Agriculture, and extracted carefully with water, chloroform being used as a preservative. This extract was evaporated in vacuo and made up to 154 c. c. At 11.10 a. m., September 30, 1907, 14 c. c. of this extract were taken. Seventy-four c. c. in all were taken by 1.45 p. m., without any special symptoms. The taste of the extract was exceedingly disagreeable. By 4.15 p. m. all but 40 c. c. had been taken; that is, an extract of over 300 grams. No untoward symptoms characteristic of milksickness were noted the following day; in fact, the writer never felt better.

To simulate the conditions which occur in herbivora, 100 grams of the dried plant from Illinois were digested with pepsin and pancreatin and the concentrated products taken by the writer in the period of one hour without the production of any serious symptoms.

SUMMARY.

To sum up, it certainly can not be said that it has been proved that milksickness is due to any constituent of *Eupatorium ageratoides.* The transmission of the disease by eating small quantities of meat or milk of animals sick with the "trembles" and the fact that cooked meat or boiled milk [a] does not produce this disorder point primarily rather to a parasitic origin, while the fact that *Eupatorium ageratoides* [b] is abundant in areas where the disease is not known and absent in some milksick areas [c] also indicates that the plant has no relation to the disease. If it does, it would be only an accidental carrier of some pathogenic organism.[d] According to reports, the same flora may be in the areas in which "trembles" occur as in those free from it, and milksickness is also said to occur where no vegetation grows (inclosed pens).[e] The disease also has diappeared from an area

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[a] Smith, C. H. Milk Sickness. Boston Med. and.Surg. Jour., vol. 77, p. 471, 1867–68.—Wood, G. B. Practice of Medicine, vol. 1, p. 465, 1858.

NOTE.—Some toxins from infected meat are not injured by boiling.

[b] Wilkinson, G. W., l. c., p. 153.—Graff, G. B., l. c., p. 361.

[c] Brewington, W. J. Milksickness. The Clinic, Cincinnati, vol. 10, p. 77, 1876.

[d] Walker, J. W., l. c., p. 483.

[e] Wilkinson, G. W., l. c., p. 153.

after simply clearing the woodland where it occurred and turning it into pasture.[a] Again, severe epidemics have occurred in winter when the foliage has disappeared, which would tend to exclude the higher, non-evergreen plants as the cause of this disorder. In fact, all the evidence in hand is against the causation of this disease by such plants, and certain analogies with cases of botulismus suggest a somewhat similar cause. If there is any truth in the statement that cattle exposed in pasture to night air especially contract the disease, this fact might suggest the more or less direct connection of some night organism as a carrier of the parasite, and certain parasites are supposed to be associated with certain localities.

Very little is known chemically of *Eupatorium ageratoides*.

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[a] Heeringen, E., l. c., p. 9.

NOTES.—A full bibliography can be found in Schuchardt, B., Die Milchkrankh. d. Nord Amerikaner, Janus, vol. 2, pp. 437, 525, 1897–98.

The most interesting experimental paper is that of Graff, while that of Drake is valuable for its fund of personal experiences as told by the settlers, and that of Schuchardt is the best literary handling of the question.

Eupatorium perfoliatum, a closely allied plant, has received some chemical attention, and a nonnitrogenous body, eupatorin, has been obtained. While the author states it will kill mice on subcutaneous injection, he fails to give the dose, and nothing can be drawn from this report as to its physiological activity.

Shamel, C. H. Eupatorin: The Active Principle of Eupatorium Perfoliatum. Am. Chem. Jour., vol. 14, p. 224, 1892.

Latin, G. Eupatorium Perfoliatum. Pharm. Jour. and Trans., 3 s., vol. 11, p. 192, 1881.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 121, PART II.

B. T. GALLOWAY, *Chief of Bureau.*

MOUNTAIN LAUREL, A POISONOUS PLANT.

BY

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PHARMACOLOGIST, POISONOUS-PLANT INVESTIGATIONS.

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ILLUSTRATION.

MOUNTAIN LAUREL, A POISONOUS PLANT.[a]

By ALBERT C. CRAWFORD, *Pharmacologist, Poisonous-Plant Investigations.*

HISTORICAL INTRODUCTION.

Many members of the Ericaceæ, or heath family, contain principles which are injurious to man and to animals. Of these the members of the genus Kalmia especially interest us on account of their wide distribution in the United States and from the fact that many cases of poisoning in animals have been attributed to them. This genus is American in origin, but is found mainly in the Eastern States. The members of this group received their generic name in honor of Peter Kalm, but their popular name, laurel, was given on account of the resemblance of their leaves to those of the English laurel tree, a member of an entirely different family.[b] On account of the beauty and perfection of their flowers they were once proposed as a national emblem.[c]

Of these, mountain laurel (*Kalmia latifolia*), shown in Plate II, is probably the most important. North of Maryland it is usually known as mountain laurel, while south of Maryland it is sometimes known as ivy.[d] It has also received many other names, as calico bush,[e] laurel,[f] sheep laurel, mountain ivy,[g] wintergreen, great laurel,[h]

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[a] The mountain laurel, *Kalmia latifolia* L., has long been recognized by many people as one of our most deadly shrubs. It is a poison fatal to live stock, especially to sheep and goats, which seem more likely than cattle and horses to browse on it. The Bureau of Plant Industry is in receipt of letters inquiring into the facts concerning its action and the methods of treating poisoned stock.

Dr. Albert C. Crawford, Pharmacologist, under the direction of Dr. Rodney H. True, Physiologist in Charge of the Poisonous-Plant Investigations of this Bureau, has given the matter laboratory study with the results here briefly stated.—B. T. GALLOWAY, *Chief of Bureau.*

[b] Kalm, P. Travels into North America, 2d ed., vol. 1, p. 263, London, 1772.

[c] Bailey, L. H. Cyclopedia of American Horticulture, 4th ed., vol. 3, p. 854, 1906.

[d] Gronovius, J. F. Flora Virgin., pt. 2, p. 160, 1743.

[e] Coulter, S. Catalogue of Flowering Plants * * * Indigenous to Indiana. Dept. Geol. and Nat. Resources of Indiana, 24th Ann. Rept., 1899, p. 607.

[f] Gronovius, J. F., l. c., p. 160.

[g] Smith, J. E. Natural History of the Rarer Lepidopterous Insects of Georgia, vol. 1, pl. 73, 1797.

[h] Cutler, M. Account of Some of the Vegetable Productions Naturally Growing in This Part of America. Amer. Acad. Arts and Sci. Mem., vol. 1, p. 442, 1785.

American laurel,[a] wicky, rose laurel, etc. The Pennsylvania mountain laurel[b] (*Rhododendron maximum*) is a closely allied species, while in California the name mountain laurel is applied to *Oreodaphne californica*,[c] a member of the family of Lauraceæ.

Mountain laurel usually occurs as a shrub, growing from 5 to 15 feet high, but in the Blue Ridge Mountains of North Carolina it has been seen reaching to a height of 25 or 30 feet.[d]

The species extends from New Brunswick and Canada to Florida, and through the Gulf States to Louisiana and Arkansas, but is especially abundant through the Eastern States along the Allegheny Mountains, where it forms dense, impenetrable thickets.[e] In spite of the name "mountain laurel" it grows on hills and banks in the lowlands, but especially along the courses of streams. The leaves are of a tough, leathery consistency and are evergreen. The flowers, which are nearly destitute of odor, have a peculiar arrangement of their stamens, which bend over with their brown anthers projecting into pockets in the corolla,[f] so that when this flower is visited by a bee they fly back, scattering the pollen over its own stigma, and also over the insect, which then carries it to other flowers, securing cross pollination. The flowers have a waxlike appearance and vary from a white to a rose color. The wood of the mountain laurel is close grained and hard and is a substitute for boxwood, and it may be used for making handles of small tools, etc.[g] The powder covering the leaves has been used as a snuff.[h] The laurel leaves have been utilized ever since the time of the colonists as one of the evergreens for Christmas decorations.[i]

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[a] Coulter, S., l. c., p. 607.

[b] Marshall, H. Arbust. Amer., p. 127, 1785.

[c] Reports of Explorations and Surveys * * for a Railroad from the Mississippi River to the Pacific Ocean, 1853–54. Senate Doc., 2d Sess., 33d Cong., vol. 13, pt. 4, p. 133, 1856.

[d] Aaron, C. E. Our Common Poisonous Plants. Cram's Magazine, 1900, vol. 2, p. 502.

[e] Sargent, C. S. Report on the Forests of North America, 10th Census, p. 98, 1884.

[f] The details as to the historical structure of this plant will be found in the following works:

Paschkis, H. Contributions to a Closer Knowledge of Some Little-Known Leaves. Pharm. Jour. and Trans., 3d ser., vol. 12, p. 86, 1881–82. Also Zeits. d. allg. oest. Apoth.-vereines, vol. 18, p. 434, 1880.

Breitfeld, A. Der anatom. Bau d. Blätter der Rhododendroideæ in Beziehung zu ihrer systematischen Gruppirung und zur geographischen Verbreitung. Botan. Jahrb., vol. 9, p. 319, 1887–88.

Vesque, Julien. Caractères des Principales Familles Gamopétales Tirés de l'Anatomie de la Feuille. Ann. des Sci. Naturel. Botan., 7th ser., vol. 1, p. 240, 1885.

Solereder, Hans. System. Anatom. d. Dicotyledonen, 1899, p. 541–551.

[g] Emerson, G. B. Trees and Shrubs of Massachusetts, vol. 2, p. 445, 1875.

[h] Browne, D. J. Trees of America, p. 364.

[i] Kalm, P., l. c., p. 264.

FLOWERING BRANCH OF MOUNTAIN LAUREL (KALMIA LATIFOLIA, L.).

Notices of this plant occur in the early botanies[a] and books of American travel. Capt. John Smith describes, in his Generall Historie of Virginia, 1624, volume I, page 10, a "Kinde of tree like Lowrell," while Hudson in 1609 mentions "rose trees" as occurring on Cape Cod. Catesby describes it under the name Chamaedaphne foliis tini, floribus bullatis umbellatis, and says distinctly that "When cattle and sheep, by severe winters deprived of better food, feed on the leaves of these plants, a great many of them die annually."[b] The Delaware Indians are said to have used a decoction of these leaves for suicidal purposes.[c]

Public attention was especially called to this plant by Peter Kalm, the Swedish botanist, after whom Linnæus named the genus Kalmia. He described it under the name "spoon tree," because the Indians at that time made spoons of this wood. During his travels in America in 1748 he noted that calves which had eaten of the leaves became "sick, swelled, foamed at the mouth, and could hardly stand," and reported from the observations of the colonists that sheep, especially young ones, died very quickly after eating of these leaves, and that horses, oxen, and cows were made sick but seldom died, as these animals ate only small quantities of the leaves. Deer and partridges were said to feed on the leaves with impunity, and the venison from these deer was harmless to man.[d] A snake was said to have been killed by dropping a tincture of this plant on its back.[e]

John Bartram, an early American botanist, was an ardent lover of, and writer on, mountain laurel, and by him it was brought to Collinson's attention, who then introduced it into England about 1734.[f] It would seem more appropriate to have named the genus after him,[g] as his work antedated that of Kalm. During General

[a] Van der Donck, A. Vertoogh van Nieu Nederland, 1650. Translated by H. C. Murphy, 1854, p. 19.—Plukenet, L. Almagest. botan., 1769, p. 106; Almagest. botan. Mantissa, 1769, p. 49.—Gronovius, J. F., l. c., p. 160.—Linnæus, C. Spec. Plant., Ed. Willdenow, vol. 2, p. 600, 1799. Spec. Plant., vol. 1, p. 393, 1753. Amœn. Acad., vol. 3, p. 13, 1764.—Trew, C. J. Plantæ Selectæ, 1750, pl. 38. Ray, J. Hist. Plant., vol. 2, p. 1927, London, 1688. [Bannister's list of 1680.]—Hudson, H. Discourse. Collections of the New York Historical Society for the Year 1809, vol. 1, p. 121.

[b] Catesby, M. Natural History of Carolina, vol. 2, p. 98, 1743.

[c] Barton, B. S. Some Account of the Poisonous and Injurious Honey of North America. Amer. Phil. Soc. Trans., 1802, vol. 5, p. 61.

[d] Kalm, P., l. c., pp. 264–265.

[e] Barton, B. S. Collections for an Essay towards a Materia Medica of the United States, pt. 2, p. 27, 1804.

[f] Aiton, W. Hortus Kewensis, vol. 2, p. 64, 1789.—Catesby, M., l. c., p. 98.

[g] Darlington, W. Memorials of John Bartram and Humphry Marshall, pp. 130, 141, 228, etc., Philadelphia, 1849.—Bartram, John. Observations, London, 1751, pp. 26 and 69.

Braddock's campaign against the French and Indians in 1755 many horses[a] were lost from eating mountain laurel. The plant was introduced into France by Michaux.[b] In 1802 George G. Thomas[c] performed some experiments with *Kalmia latifolia* and *K. angustifolia* on himself, on a friend, and on some dogs. These experiments he embodied in an inaugural dissertation which was presented to the University of Pennsylvania. Six to 15 grains (0.4 to 1.0 gram) of the dried leaves produced distinctly unpleasant symptoms—rapid pulse, a feeling of fullness with pain in the head, throbbing of the temples, with nausea, vomiting, and dilatation of the pupils. In dogs the administration of a decoction of 30 grains (2 grams) was followed by marked salivation, with stupor, rapid respiration and purgation, paralysis, and finally convulsions. Thomas made the interesting observation that if the laurel was mixed with lard the toxic symptoms were much lessened. He examined the distillate from the leaves for an essential oil, but failed to find any.

After Thomas, several experimenters reported on the action of mountain laurel upon themselves. Bigelow,[d] who saw the dried leaves taken in doses up to 20 grains without producing symptoms, questioned if the leaves had a specific action, and traced any injurious effect they might exert to their indigestibility. Others, as Osgood,[e] Stabler,[f] and an anonymous author in the Boston Medical and Surgical Journal, volume 10, page 213, reported severe symptoms on themselves.

This action was compared with that of Veratrum.[g] From this time on few reports of experiments were published, yet the number of cases of poisoning in stock reported to the Department of Agriculture induced the Commissioner to call attention to this subject in his report of 1863.[h] Sheep are the animals usually reported as affected by the plant. Under ordinary conditions, however, eastern-bred sheep will not eat the plant unless they are starved or their supply of green or attractive food has been cut off.

As is well known, most of the cases of poisoning occur in winter,[i] when the laurel is the only green plant around, although western-bred

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[a] Barton, B. S., l. c., p. 60.

[b] Browne, D. J. Trees of America, p. 364.

[c] Thomas, G. G. Inaugural Dissertation on the Kalmia Latifolia and Angustifolia, Philadelphia, 1802.

[d] Bigelow, J. Amer. Med. Bot., vol. 1, p. 140, 1817.

[e] Bigelow, J., l. c., vol. 3, p. 185, 1820.

[f] Stabler, R. H. On Kalmia Latifolia. Amer. Jour. Pharm., n. s., vol. 10, p. 241, 1845.

[g] Medical Properties of the Kalmia Latifolia. Boston Med. and Surg. Jour., vol. 10, p. 213, 1834.

[h] Report of the Commissioner of Agriculture for 1863, p. 242.

[i] Remarkable Instance of the Absence of Animal Instinct. Penny Magazine, vol. 7, p. 283, 1838.

sheep if suddenly turned into a laurel area may eat it at any time. As the leaves are tasteless and of a tough, leathery consistency, it is very evident why animals will not eat the plant under ordinary conditions.

A good illustration of actual poisoning is given by Rusby[a] where out of a flock of 1,000 sheep which escaped into a laurel area, at least 27 showed symptoms of poisoning. Those affected were mainly the young ones. In these cases the tracks on the snow around the bushes and the presence of leaves in the stomach showed conclusively the cause of the trouble. Halsted[b] reported poisoning in cows after eating laurel wreaths which had been thrown from a cemetery into their pasture. A striking case occurred in the National Zoological Park, Washington, D. C., where six Angora goats were poisoned by laurel thrown to them by visitors; later, a Diana monkey died with typical symptoms after eating the leaves held to it by a visitor. The leaves of the plant were found in the monkey's stomach. The post-mortem examination in this case was negative. Since these poisonings occurred visitors have been prohibited from carrying laurel into the park.

Barton in 1802[c] called attention to the fact that the honey made from *Kalmia angustifolia* was poisonous to man, and while no direct proof[d] has been published that honey made from *K. latifolia* is poisonous it is perfectly logical to suppose that it is, as Plugge found that honey made from *Rhododendron ponticum*,[e] a closely related plant, gave the same chemical and physiological tests on frogs and mice which he considers characteristic of its active principle, andromedotoxin. *Rhododendron ponticum* is the plant which is supposed to have yielded the honey which poisoned Xenophon's[f] army.

Under these circumstances the Secretary of Agriculture advised against raising bees in the neighborhood of mountain laurel. An unpublished report is on file at this office of investigations in which extracts of mountain laurel were mixed with honey and fed to bees.

[a] Rusby, H. H. The Poisonous Properties of Mountain Laurel. Drug. Cir. and Chem. Gaz., vol. 46, p. 27, 1902.

[b] Halsted, B. D. Eighth Annual Report of the New Jersey Agricultural College Experiment Station for 1895, p. 355, 1896.

[c] Barton, B. S. Some Account of the Poisonous and Injurious Honey of North America. Amer. Phil. Soc. Trans., 1802, vol. 5, p. 59.

[d] American Bee Journal, 1896, pp. 92, 146, 246, 262.—Root, A. I. A B C of Bee Culture, p. 249.—Honey from Mountain Laurel. American Bee Journal, vol. 35, p. 825, 1895.

[e] Plugge, P. C. Giftiger Honig von Rhododendron ponticum. Arch. d. Pharm., vol. 229, p. 554, 1891.—Thresh, J. C. Notes on Trebizonde Honey. Pharm. Jour. and Trans., 1887–88, vol. 18, pp. 397, 404.

[f] Pliny. Nat. Hist. (Translated by Bostock and Riley), vol. 4, p. 341.—Abbott, K. E. Letter, in Proc. Zoolog. Soc. London, pt. 2, p. 50, 1834.

The name of the investigator can not now be ascertained. These bees are said to have shown no symptoms, but the honey they made produced typical symptoms in two persons who ate it.[a] It has been claimed that the flesh of birds after eating laurel is poisonous to man,[b] but Wilson,[c] Audubon,[d] and Aaron[e] state that they have frequently eaten without injury partridges whose craws were filled with laurel leaves and buds. It is probable that many of these cases of poisoning were really due to ptomaines, as they usually occurred from undrawn animals.

There are few cases in man of poisoning with laurel. Children are said to have been poisoned by eating the plant in mistake for *Gaultheria procumbens*,[f] although there are no published cases to that effect. Laurel is claimed to be used in certain liquors to render them more intoxicating.[g] Barton[h] noted that the flowers of *Kalmia latifolia* would produce a vesicular eruption in certain persons.

EFFECT OF MOUNTAIN LAUREL ON SHEEP.

Stable-fed sheep and lambs were turned into an inclosed area in which the mountain laurel was the only green plant. These sheep, which were kept under observation for several hours, refused to do more than merely nibble at the leaves, and when placed in grassy areas where this plant was growing they positively refused to touch it. These observations agree with those of Wood[i] on *Kalmia angustifolia*. Other animals besides sheep seem disinclined to eat it. Kalm reported in 1754 that the leaves of the trees in Pennsylvania were devoured by a worm, but that the mountain laurel leaves were untouched.[j]

Sheep weighing about 50 pounds (25 kilos) were fed with doses of 5, 10, 15, 25, and 35 grams of the dried ground-up leaves inclosed in gelatine capsules without producing poisonous symptoms. Fifty grams, when given to a sheep weighing 33.5 kilos, induced a staggering gait and slight salivation, but doses of 85 grams would cause death in a very few hours unless diarrhea set in. Under these

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[a] Unpublished answer to inquiry.

[b] Barton, B. S., l. c., p. 60.—Elliot, D. G. "Game Birds" of the United States. Report of the Commissioner of Agriculture for 1864, pp. 363, 364, 1865.

[c] Wilson, A., and Bonaparte, C. L. Amer. Ornithology, vol. 2, p. 319, Edinburgh, 1831.

[d] Audubon, J. J. Birds of America, vol. 5, p. 79, 1871.

[e] Aaron, C. E. Cram's Magazine, vol. 2, p. 502, 1900.

[f] Unpublished correspondence. (G. Watkins, 1896.)

[g] Chesnut, V. K. Principal Poisonous Plants of United States. U. S. Dept. Agr., Div. Bot. Bul. 20, p. 45.

[h] Barton, B. S. Collections for an Essay Towards a Materia Medica of the United States, p. 35, 1804.

[i] Wood, T. F. Is Sheep Laurel Poisonous to Sheep? American Agriculturist, vol. 42, p. 66, 1883.

[j] Kalm, P., l. c., vol. 1, p. 266.

conditions sheep have survived this dose. In starved animals no doubt smaller doses would be poisonous.

One experiment was with a sheep about 7 years old; weight about 22.5 kilos. On June 1, 1905, at 11:05 a. m., the temperature[a] was 104.5° F., respiration 60, pulse 90 per minute. A slight secretion from the nostrils was present owing to a coryza; pupils about one-fourth of an inch wide; the conjunctival, buccal, and mucous membranes normal. Eighty-five grams of powdered dried laurel leaves in sealed gelatine capsules were given. The feeding lasted twenty-five minutes.

Following the administration of the capsules little inclination to eat was manifested, urination and slight defecation taking place during the first hour. At 1 p. m., respiration was 110 per minute, pulse 117, temperature 104° F. Marked disinclination to move was shown, the sheep permitting itself to be easily turned on its side. It ate only sparingly. Two hours after taking the laurel leaves urination was repeated and slight emesis set in, followed soon by mental dullness, as shown by decreased attention to surrounding objects, with a loss of alertness, while the face took on a sleepy appearance and saliva began to accumulate about the mouth. Respiration was somewhat labored and the unsteadiness in gait became marked. Two and three-fourths hours after eating the laurel the sheep assumed an awkward attitude in standing, the hind legs being set wide apart. Repeated emesis became a prominent feature and continued for about an hour, the ejecta being thin and mustard-like. Apparently to facilitate breathing, the mouth was kept open most of the time. Weakness and unsteadiness increased until three and one-fourth hours after eating the laurel. At this time it was difficult for the animal to stand.

At 2:46 p. m. the temperature was 107° F., respiration 50 per minute, pulse 124. The pupils were of the same size as before the feeding. The abundant nasal secretion at this time became a very marked symptom, and continued so throughout the history of the case. Weakness increased until the animal could not stand, and a diminished sensitiveness to skin irritation was noted. Death ensued quickly at 3:06 p. m. No convulsions were noted at any time.

The post-mortem examination was made at once. The sheep appeared to be well nourished. Some mustard-colored ejecta were found in the trachea as well as in the bronchioles. The lungs crepitated markedly, but showed no special amount of fluid. The pleural cavity contained no increased amount of fluid. The mucous membranes were not discolored. The heart contained no clots, was not dilated, and contained only a little dark blood. The stomach was full of food and its walls showed no signs of irritation. The intestines

[a] In all cases the temperature was taken by the rectum.

were apparently congested, but showed no hemorrhages. The small intestines were more or less filled with thin normal-looking contents. The kidneys appeared normal, the bile was of a dark-green color, and the bladder was contracted and empty. The central nervous system was not examined.

The bile from this sheep, which amounted to about 20 c. c., was treated with alcohol, and after evaporating off the alcohol in vacuo was precipitated with lead acetate. The filtrate when freed from lead by H_2S and injected into guinea pigs produced absolutely no symptoms characteristic of laurel poisoning.

On May 22, 1905, one of the yearlings previously used, weighing 24.5 kilos (49 pounds), was fed with 90 grams of powdered dried laurel leaves in sealed gelatine capsules, the feeding beginning at 1:15 a. m. and taking about fifteen minutes. Before feeding, the pulse was 135, respiration 50 per minute, rectal temperature 103.9° F. After forty-five minutes an increased secretion of saliva became evident about the mouth and the sheep nibbled slightly at the grass. At 11:15 p. m. the temperature was 105° F., the head was held low, respiration was somewhat labored, and saliva ran profusely from the mouth; pulse 104, respiration irregular, 144 per minute, pupils unchanged. Two and a quarter hours after feeding, the animal became less active, the ears were held back, and the general aspect was that of a sheep half asleep. Respiratory and salivary symptoms continued, the animal standing with the hind legs wide apart and showing evidence of weakness in the hind quarters by a staggering gait.

Four hours after feeding, profuse nasal secretion became a conspicuous feature and weakness increased to such a degree that the subject was unable to stand; respiration 120, temperature 104° F. The nostrils were moist; pupils normal. Convulsions soon appeared. with sensitiveness to touch persisting in the conjunctiva; knee jerks active, pupils a trifle dilated. Ten minutes later emesis followed. Respiration was apparently increasingly difficult. The hind legs seemed stiff. At 3:50 p. m. the pulse was 104 per minute, temperature 103.8° F., with continued attempts at emesis and repeated tossing of the head from side to side; pupils normal. Death ensued at 9:30 p. m.

No discoloration of the mucous membranes was noted, and constipation prevailed during the period of observation. At no time was a marked thirst shown. The post-mortem examination made the following day showed the trachea injected and very moist and two or three teaspoonfuls of pure serum in the pleural cavity. The lungs were œdematous. The auricles were relaxed and filled with black clots; the left ventricle contained very little black blood, while the right ventricle contained very much more. The abdomen was distended with gas. The stomach was partially filled with food; the second and third stomach walls showed no special lesions, but

the intestines throughout showed marked hemorrhagic enteritis. The small intestines contained very little solid matter, but there was some well-formed fecal matter in the cœcum. The liver was perhaps a trifle pale and the kidneys were slightly injected. The spleen showed no macroscopic change. In none of these cases was it possible to secure the urine for examination, as the bladder was found empty.

On October 14, 1905, a five-year-old (?) sheep, having a temperature of 101.8°F., at 1:20 p. m. was given 90 grams of fresh laurel leaves ground up and mixed with meal. The ration was practically all eaten at 3:20 p. m., when the temperature stood at 104° F. At 6 o'clock on the next morning a failure of appetite, together with slobbering, was noted. Numerous soft stools were found in the pen during the day. At 10:12 a. m. increased salivary secretion produced a frothy appearance about the mouth and the sheep held its head low. At 2:15 p. m. slight emesis and marked secretion of nasal mucus occurred accompanied by a temperature of 103.5° F. Twenty-five hours later the slobbering had ceased, but the appetite had not returned and the temperature stood at 102.9° F. Twenty-two hours later (1:45 p. m., October 17) the temperature was 103.5° F. and the animal seemed normal. The presence in the pen of numerous soft stools was noted. The sheep recovered.

EFFECT OF MOUNTAIN LAUREL ON RABBITS.

On February 6, 1905, a rabbit weighing 2,096 grams received hypodermically one drop of aqueous extract of laurel (1 gram of dried leaves in 3.75 c. c. of water). Further administrations were made as follows: February 13, 2 drops; February 21, 3 drops; February 25, 4 drops; February 28, 6 drops; March 3, 9 drops; March 7, 12 drops; March 10, 14 drops; March 22, 20 drops. On the last date evidence of laurel action appeared and a slight loss of appetite was noted. On March 30, 25 drops were administered as before, followed on April 5 by 30 drops. At this time the animal weighed 1,828.5 grams. At 9:49 a. m. the temperature was 100.9° F., the administration of the extract following three minutes later. The resulting events were as follows: 10:05 a. m., mouth moist; 10:50 a. m., convulsions; 11:15 a. m., could not stand; 11:55 a. m., could sit up in usual posture; 1:54 p. m., appeared normal. At 3:50 p. m. the temperature was 103.3° F. The animal lived about a year after the close of this investigation.

A rabbit weighing 1,559 grams, which had not received any previous injections, was given hypodermically at 9:54 a m., April 5, 1905, 30 drops of the extract used in the preceding case. The temperature five minutes before administration was 100.8° F. The following symptoms developed rapidly: After nine minutes, interfer-

ence with the gait, followed shortly by urination and increasing evidences of weakness, with marked difficulty in standing, was noted; slight convulsions were seen 35 minutes after administration, repeated at intervals during the following hour and a quarter; at 11:15 a. m. paralysis of the hind legs led to a straddling attitude, head held back, and sphincter relaxed. The temperature at 11:50 a. m. was 95.2° F. At 1:54 p. m. the animal was much better. It could walk but staggered. At 3:49 p. m. the temperature was 102.3° F.; condition good. The rabbit seemed apparently all right until April 13, when convulsions occurred which were followed by death.

GENERAL SYMPTOMS OF POISONING.

The symptoms commonly observed are salivation, tearing, an increased flow of secretion from the nose, emesis with convulsions, and later paralysis of the limbs. On post-mortem examination the main macroscopic lesion is dilation of the vessels of the intestinal walls,[a] and if the case is not too acute, hemorrhages into the intestinal walls occur, resembling what is known as rhododendron poisoning. The aqueous extract of the flowers produced the same symptoms on rabbits as that made from the leaves.

ACTIVE PRINCIPLE.

Comparatively little chemical work has been done with mountain laurel save testing for a volatile oil[b] and arbutin.[c] Most of the chemical work has been done on a closely related plant, *Andromeda japonica*, now known as *Pieris japonica*. Eykmann[d] isolated an amorphous glucosidal body which he called asebotoxin, which melted at 120° C. and had a lethal dose for rabbits of 3 mg. per kilo. Plugge[e] studied the same plant, making his first report in 1882. He extracted the plant with water, then precipitated with lead acetate and lead subacetate, and after removing the lead with sulphureted hydrogen or sodium sulphate concentrated the fluid in vacuo at 50° C. This colorless fluid was then shaken out with chloroform, and the chloroform on evaporation left transparent, noncrystalline scales, which he called andromedotoxin. The mother liquid gave an amorphous

[a] In one case of poisoning by *Andromeda polifolia*, this was noted by Plugge. Ueber d. Vorkommen d. Andromedotoxins in Andromeda Polifolia. Arch. d. Pharm., vol. 221, p. 814, 1883.

[b] Stabler R. H. On Kalmia Latifolia. Amer. Jour. Pharm., n. s., vol. 10, p. 246.—Bullock, C. On Kalmia Latifolia. Amer. Jour. Pharm., n. s., vol. 14, p. 260, 1848.

[c] Kennedy, G. W. Arbutin in Kalmia Latifolia. Amer. Jour. Pharm., vol. 47, p. 5, 1875.

[d] Eykmann, I. F. Sur le Principe Toxique de l'Andromeda Japonica. Rec. d. Travaux Chim. des Pays-Bas, vol. 1, p. 224, 1882. Phytochem. Notizen u. einige japan. Pflanzen. Abhandl. d. Tokio Daigaku, No. 10, p. 1. 1883.

[e] Plugge, P. C. Ueber Andromedotoxin. Arch. d. Pharm., vol. 221, p. 1, 1883.

body, andromedorubrin. This andromedotoxin gave no precipitates with alkaloidal reagents and did not reduce Fehling's solution, but gave certain color reactions and produced distinct and characteristic symptoms on injection into guinea pigs and frogs—severe retching, which, however, is absent after large doses; disturbances of respiration; convulsions, and paralysis.

The characteristic color reactions are as follows:

(1) Concentrated sulphuric acid gives a dark reddish brown color and dissolves it gradually. On warming it becomes a deeper red. On dilution with water this passes into a light mulberry-red, disappearing with alkalis.returning with H_2SO_4.

(2) Evaporation with dilute H_2SO_4 (1:5) on water bath causes rose-red color. If the body is pure there is no odor, but if not pure there is an odor of ericinol, due to the decomposition of ericolin, an attached body.

(3) Dilute HCl acts the same as H_2SO_2, only it gives a color more nearly violet-red.

(4) Dilute phosphoric acid, 25 per cent, gives a mulberry-red color. By this means 0.0000005 gram of andromedotoxin can be recognized.

Especial emphasis is laid on the second and fourth reactions.[a] Plugge also extended his studies to other members of this group. The first of these to be examined was *Andromeda polifolia.* He made the plausible claim that because the chloroform "shaking" from the aqueous extract freed from extraneous matter by lead gave the same color reactions and produced the same action in animals as that from *Pieris japonica* it contained the same active principle, but he admitted that this body was much less active than the andromedotoxin obtained from *Pieris japonica.* He explained this weakness as being due to the fact that the plant was grown on a different soil and that the active principle varied from that of *Pieris japonica* much as the active principle of the various species of Digitalis and Aconitum vary.[b]

In using this method with *Leucothoë catesbaei*[c] Plugge noted that the first six or seven chloroform shakings gave an amorphous residue, while the seventh to the ninth gave a white crystalline body from which he obtained the characteristic physiological action and color reactions of andromedotoxin.

From *Chamaedaphne calyculata* he obtained some crystalline deposit, but in this case from the lack of material was unable to

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[a] Plugge, P. C. Vorkommen von Andromedotoxin in verschied. Ericaceen. Arch. d. Pharm., vol. 223, p. 906, 1885.

[b] Plugge, P. C. Ueber d. Vorkommen d. Andromedotoxin in Andromeda Polifolia. Arch. d. Pharm., vol. 221, p. 818, 1883.

[c] Plugge, P. C. Vorkommen von Andromedotoxin in verschied. Ericaceen. Arch. d. Pharm., vol. 223, p. 905, 1885.

positively identify it as crystalline andromedotoxin. The material obtained from this plant was less active physiologically than that obtained from *Pieris japonica*. Crystals were also obtained from *Azalea indica*.

In 1887 Plugge[a] and his pupil de Zaayer[b] made a more extended study of the andromedotoxin obtained from *Rhododendron ponticum*. They summed up the previous chemical work and studied the active principle pharmacologically. They claimed that the body shaken out by the chloroform could be precipitated from alcohol or chloroform solution by ether in the form of crystalline needles. Muto failed to obtain these needles from *Pieris japonica*, the plant Plugge first worked with. This body contained carbon, hydrogen, and oxygen, but no nitrogen, and melted at 228° to 229° C. Plugge and de Zaayer gave it the empirical formula $C_{31}H_{51}O_{10}$, although the figures for this conclusion were not exact. It was readily soluble in water and alcohol, but very slightly in ether. They stated that it was more soluble in cold than in hot water, although Plugge elsewhere states the opposite. In water, alcohol, and amyl alcohol it turns the plane of polarization to the left, while dissolved in chloroform it turns it to the right. It gives no precipitate with alkaloidal reagents. When subcutaneously injected, 0.0001 gram caused death in a frog (*Rana temporaria*) in a few hours.

This conjoint paper apparently so settled the question as to indicate that all that was necessary to determine the presence of andromedotoxin was to ascertain if the chloroform shaking from the plants gave the same physiological action and the same color reaction as that described for andromedotoxin. Plugge did this with *Kalmia latifolia* and from its action on frogs decided that the fluid extract contained one-half of 1 per cent of andromedotoxin. By this method he decided that andromedotoxin was present in the following plants:

Pieris japonica Thunb.
Andromeda polifolia L.
Leucothoë catesbaei (Walt.) Gray.
Chamaedaphne calyculata (L.) Moench.
Rhododendron grande Wight.
Rhododendron barbatum Wall.
Rhododendron fulgens Hook. f.
Rhododendron cinnabarinum Hook. f.
Rhododendron puniceum Roxb.
Rhododendron ponticum L.
Rhododendron chrysanthum L.
Rhododendron hybridum Ker.
Rhododendron falkoneri Hook. f.
Rhododendron maximum L.
Kalmia latifolia L.
Kalmia angustifolia L.
Azalea indica L.
Monotropa uniflora L.
Pieris formosa Don.
Pieris ovalifolia Don.

[a] Plugge, P. C. Ueber Andromedotoxin. Arch. d. Pharm., vol. 221, p. 12, 1883.

[b] Zaayer, H. G. de. Untersuch. ü. Andromedotoxin. Arch. f. gesam. Physiol., vol. 40, p. 480, 1887.—Plugge, P. C. Andromedotoxin. Verhandl. d. X internat. med. Cong., vol. 2, pt. 4, p. 28, 1891.

Plugge concluded that andromedotoxin was the active principle of the Ericaceæ in general.

In the case of *Rhododendron hirsutum*, Plugge[a] found that the chloroform shaking failed to produce any immediate symptoms in frogs, but three hours after injection convulsions with slight respiratory disturbance occurred, with the secretion of mucus from the mouth. These symptoms completely disappeared, differing from those of andromedotoxin. This extract gave no reactions with dilute or concentrated HCl, 25 per cent phosphoric acid, and dilute H_2SO_4. In studying the distribution of andromedotoxin, Plugge makes the interesting observation that concentrated solutions of *Erica vulgaris*, now known as *Calluna vulgaris*, injected subcutaneously into frogs cause symptoms resembling those of andromedotoxin poisoning, yet chemically no trace of this body could be found.[b]

Lasché also studied the action of extracts of *Kalmia latifolia* and *K. angustifolia* on animals, and corroborated Plugge's data, but isolated no pure body and made no chemical analysis. He used the berries in his work.[c]

Matusow,[d] while accepting the belief that andromedotoxin is the active principle of the leaves, says that the chemical reactions of the root correspond with those of andromedotoxin, except with hydrochloric acid. He claims the presence of calcium, magnesium, aluminum, manganese, and iron in the roots.

Archangelsky[e] examined another member of the Ericaceæ, the *Rhododendron chrysanthum*, a native of Siberia, and isolated a crystalline principle, rhododendrin, with the empirical formula $C_{16}H_{22}O_7$, which was inactive to frogs, and a crystalline body, rhododendrol, which acted on frogs similarly to camphor. He also claimed the presence of andromedotoxin, but did not isolate it. He examined *Rhododendron ponticum* and obtained the same color reactions and physiological reactions found by Plugge with andromedotoxin.

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[a] Plugge, P. C. Andromedotoxinhaltige Ericaceen. Arch. d. Pharm., vol. 229, p. 553, 1891.

[b] Plugge, P. C. Fortgesetzte Untersuch. ü. d. Verbreit. d. Andromedotoxins in d. Familie d. Ericaceen. Arch. d. Pharm., vol. 27, p. 171, 1889.

[c] Lasché, A. J. M. Examination of Some of the Poisonous Ericaceæ of North America. Pharm. Rund., vol. 7, p. 208, 1889.

[d] Matusow, H. Analysis of the Root of Kalmia Latifolia. Amer. Jour. Pharm., vol. 69, p. 341, 1897.

[e] Archangelsky, K. Ueber Rhododendrol, Rhododendrin und Andromedotoxin. Arch. f. exper. Path. u. Pharm., vol. 46, p. 313, 1901.

Hayashi and Muto failed to obtain crystalline andromedotoxin from *Pieris japonica* by using Plugge's method.[a]

So it can not be said that the active principle from mountain laurel has been actually isolated in a pure state. Using Plugge's method. the writer failed to obtain crystals from mountain laurel, but obtained crystals by a different method, namely, from the filtrate after ether precipitation. Plugge's principle is precipitated by ether. In no case has the writer found the ether precipitate physiologically active, and an ether extract of the crude plants possessed the toxic action of the plant. Full details as to the chemical and pharmacological investigations will be made later.

Laboratory animals, as guinea pigs and rabbits, after subcutaneous injection show tearing, retching, convulsions, and later paralysis. This physiological reaction can be used as a guide in the isolation of the active principle. Before death in males there is an ejection of semen.

REMEDIAL AGENTS.

The fact that sheep which have diarrhea have recovered from toxic doses of mountain laurel would suggest purgative treatment. Farmers very commonly administer lard in this condition, and this no doubt acts by hindering absorption. The use of lard in laurel poisoning has been substantiated by the experiments of Thomas, who found that the animals were less likely to become poisoned if lard was administered. In case vomiting and purgation do not occur, this result should be encouraged by the usual agents.[b] To induce vomiting, 60 milligrams of apomorphine hydrochlorate may be given subcutaneously and purgation may be encouraged by giving 2 to 6 ounces (60 to 180 grams) of epsom salts dissolved in water as a drench. The treatment is purely symptomatic and no true antidote is known.

It seems of interest to ascertain whether the action on the glandular secretion noted can not be obtained free from great toxicity by a change in the chemical structure of the active principle.

MEDICINAL ACTION.

Thomas treated one case of diarrhea by means of a decoction of *Kalmia latifolia*, and the leaves have also been used empirically in the treatment of certain stages of fever. Locally an ointment has

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[a] Hayashi, H., and Muto, K. Ueber Athmenversuche mit einigen Giften. Arch. f. exper. Path. u. Pharm., vol. 47, p. 220, 1902.

[b] Remarkable Instance of the Absence of Animal Instinct. Penny Magazine, vol. 7, p. 283, 1838.

been employed for various forms of skin diseases, such as tinea, etc., but now it has fallen entirely out of use. A tincture is still used by homeopathic physicians.[a] The only indications for its use would be as a substitute for some member of the veratrine or aconitine family.

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[a] Boericke and Tafel. Amer. Homeop. Pharm., 1896, p. 279.

NOTE.—*Kalmia angustifolia* is used by the Cree Indians as a tonic. Bul. Torrey Bot. Club, vol. 12, p. 53, 1885.

121—II

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 121, PART III.

B. T. GALLOWAY, *Chief of Bureau.*

RESULTS OF LOCO-WEED INVESTIGATIONS IN THE FIELD.

BY

C. DWIGHT MARSH,
EXPERT, POISONOUS-PLANT INVESTIGATIONS.

LABORATORY WORK ON LOCO-WEED INVESTIGATIONS.

BY

ALBERT C. CRAWFORD,
PHARMACOLOGIST, POISONOUS-PLANT INVESTIGATIONS.

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B. P. I.—340.

RESULTS OF LOCO-WEED INVESTIGATIONS IN THE FIELD.[a]

By C. DWIGHT MARSH, *Expert, Poisonous-Plant Investigations.*

FIELD WORK.

The word "loco," from the Spanish, meaning crazy, has been applied for a great many years to a disease of stock and sheep in the semiarid region of the West. There has been a general belief among stockmen that the disease is caused by certain weeds known as loco weeds. The name loco weed has been applied to a large number of plants, but two are considered especially obnoxious—*Aragallus lamberti* and *Astragalus mollissimus*.

More or less desultory investigations by scientific men have been made on this subject, the general result of which has been to imply that the disease was produced by some other cause than the loco plants. Later investigations have made it seem quite probable that the cause of the disease must be sought in some other direction. The investigations here recorded were undertaken to clear up first of all the doubt concerning the source of trouble.

The first essential point was to demonstrate whether the loco weeds did or did not cause the disease. The work of the first season, the summer of 1905, accomplished this demonstration in a very satisfactory way. It was clearly proved that *Aragallus lamberti* would

[a] For many years stockmen of the plains east of the Rocky Mountains have reported great losses due to a somewhat undefined cause known as "loco." It has been estimated that the losses from this source in Colorado alone have reached the sum of a million dollars per annum. A thorough investigation of the loco problem by the Bureau of Plant Industry, both in its field and laboratory aspects, was undertaken by the office of Poisonous-Plant Investigations, under the direction of Dr. Rodney H. True, Physiologist in Charge, the field work being in the hands of Dr. C. Dwight Marsh, Expert, and the laboratory work in those of Dr. Albert C. Crawford, Pharmacologist.

The importance of the results obtained, together with the fact that the publication of the rather extensive evidence accumulated is likely to be somewhat delayed, has made it seem desirable to present at once a brief summary of the results obtained.—B. T. GALLOWAY, *Chief of Bureau.*

poison horses, sheep, and cattle and that *Astragalus mollissimus* would poison horses. *Astragalus mollissimus* does not poison cattle because they very rarely eat it.

The work of the second season, the summer of 1906, was mainly devoted to a diagnosis of the disease. The external symptoms described by stockmen were in general corroborated. The principal symptoms are the lowered head, rough coat, slow, staggering gait, movements showing lack of muscular coordination, sometimes more or less paralytic symptoms, a generally diseased nervous system, and in the later stages of the disease extreme emaciation.

The principal pathological changes are pronounced anemia of the whole system, diseased stomach walls, and in acute cases a congested condition of the walls of the stomach, while in chronic cases there are frequently ulcers. Generally speaking, locoed cattle have ulcers in the fourth stomach. There is an excess of fluids in the various cavities of the body. This is especially noticeable in the epidural space of the spinal canal. Here the effusion is more or less organized, presenting the appearance of a gelatinous mass, which is especially abundant in the lumbar region and about the exits of the spinal nerves. In most locoed females the ovaries are found in a diseased condition.

The third stage of the work was the devising of remedial measures. This was undertaken in the summer of 1907. This work naturally had two phases, (1) attempts to eradicate the weed and (2) attempts to cure the locoed animals.

In regard to the possibility of killing the weeds, it was found that this could readily be done in the case of fenced pastures. This is especially feasible with *Astragalus mollissimus*, because it occurs in comparatively small patches. *Aragallus lamberti* has a wider distribution, but it is not at all impossible to destroy this weed when in pastures. There seems to be no way of ridding the ranges of these weeds, however.

In regard to the second phase of remedial work, it was found that locoed cattle can in most cases be cured by a course of treatment with strychnine, while locoed horses can generally be cured by a course of treatment with Fowler's solution. The animals under treatment must not be allowed to eat the loco weed and should be given not only nutritious food but, so far as possible, food with laxative properties. To this end magnesium sulphate was administered to correct the constipation which is almost universal among locoed animals. It should be noted, too, that magnesium sulphate may serve to some extent as an antidote to the poison.

It may be added, in regard to the question of immunity, that loco poisoning comes on in a slow and cumulative manner, so that there is no possibility of animals becoming immune.

LABORATORY WORK ON LOCO-WEED INVESTIGATIONS.

By Albert C. Crawford, *Pharmacologist, Poisonous-Plant Investigations.*

SUMMARY OF LABORATORY WORK.

(1) Conditions analogous to those found in locoed animals occur in portions of the world other than the United States, especially in Australia.

(2) The symptoms described in stock on the range can be reproduced in rabbits by feeding extracts of certain loco plants. Those especially referred to here under the term "loco plants" are *Astragalus mollissimus* and *Aragallus lamberti.*

(3) The production of chronic symptoms in rabbits is a crucial test of the pharmacological activity of these plants.

(4) It is the inorganic constituents, especially barium, which are responsible for this poisonous action, at least in the plants collected at Hugo, Colo.

(5) There is a close analogy between the clinical symptoms and pathological findings in barium poisoning and those resulting from feeding extracts of certain of these plants. Small doses of barium salts may be administered to rabbits without apparent effect, but suddenly acute symptoms set in analogous to those reported on the ranges.

(6) The administration of sulphates, especially epsom salts, to form insoluble barium sulphate would be the chemical antidote which would logically be inferred from the laboratory work, but of necessity these sulphates would have to be frequently administered, and their value after histological changes in the organs have occurred remains to be settled. But the treatment of acute cases of barium poisoning in man is not always successful, even when sulphates combined with symptomatic treatment are employed.

(7) Loco plants grown on certain soils are inactive pharmacologically and contain no barium. In drying certain loco plants the

barium apparently is rendered insoluble, so that it is not extracted by water, but can be extracted by digestion with the digestive ferments.

(8) In deciding whether plants are poisonous it is desirable to test not merely the aqueous or alcoholic extract, but also the extracts obtained by digesting these plants with the ferments which occur in the gastro-intestinal tract.

(9) It is important that the ash of plants, especially of those grown on uncultivated soil, as on our unirrigated plains, be examined for various metals, methods similar to those by which rocks are now analyzed by the United States Geological Survey being used.

(10) It is desirable to study various obscure chronic conditions, such as lathyrism, with reference to the inorganic constituents of the Lathyrus and other families of plants.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 121, PART IV.

B. T. GALLOWAY, *Chief of Bureau.*

THE SOURCES OF ARSENIC IN CERTAIN SAMPLES OF DRIED HOPS.

BY

W. W. STOCKBERGER,

EXPERT, DRUG-PLANT INVESTIGATIONS.

ISSUED FEBRUARY 21, 1908.

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B. P. I.—341.

THE SOURCES OF ARSENIC IN CERTAIN SAMPLES OF DRIED HOPS.[a]

By W. W. STOCKBERGER, *Expert, Drug-Plant Investigations.*

INTRODUCTION.

For several years considerable attention has been given in England to the question of the origin of the arsenic sometimes found there in beer.[b] Some students of the question have pointed out glucose,[c] malt,[d] and hops[e] as possible sources of this substance. The occasional detection of minute quantities of arsenic in dried hops has furthered the belief that hops should be carefully examined for traces of this undesirable substance, a view which finds partial support in some experiments made with hops dried by each of the two processes used in England.[f] In one of these, known as the "direct" process, the hops are dried over open fires and are thus exposed to all the combustion products arising therefrom. In the other, or "indirect" process, a current of pure heated air is caused to pass through the

[a] The growing and curing of hops has been a subject of investigation in the Bureau of Plant Industry during the past two years by the office of Drug-Plant Investigations, under the direction of Dr. Rodney H. True, Physiologist in Charge. The execution of the work in both field and laboratory has been chiefly in the hands of Dr. W. W. Stockberger, Expert. In connection with these investigations, that phase concerning the occurrence of arsenic in hops has been touched upon with fruitful results, which are here summarized. Since the conclusions reached have an important bearing on matters of considerable economic importance, their immediate publication is deemed desirable.—B. T. GALLOWAY, *Chief of Bureau.*

[b] Royal Commission on Arsenical Poisoning, London, 1901–1903. Report of the Medical Officer of Health for the City of London, No. 86.

[c] Windisch, W. Wochenschr. f. Brauerei, vol. 18, p. 30, 1901.—Hantke, E. Letters on Brewing, vol. 1, pp. 16–21, 1901.—Petermann, A. Ann. Sci. Agron., vol. 2, p. 396, 1901.

[d] Chapman, A. C. Analyst, vol. 26, p. 10, 1901.—Fairley, T. Analyst, vol. 26, p. 177, 1901; Pharm. Jour., vol. 65, pp. 634, 738, 1900.

[e] Baker, J. L., and Dick, W. D. Jour. Soc. Chem. Ind., vol. 23, p. 174, 1904.

[f] Duncan, C. County Analyst's Annual Report to the Worcestershire County Council, 1905, Appendix I, pp. 22–24.

hops, which do not come into direct contact with the gases or fumes from the fires. From the experiments cited the conclusion is drawn that hops dried by the indirect process are arsenic free.[a]

It is known, however, that traces of arsenic sometimes occur in hops which have been dried by the indirect process, a condition which has been urged in England as an argument against the purchase of imported hops, thus rendering more difficult the sale abroad of those grown in the United States.

Since under the ordinary conditions of hop production in the United States there is a surplus which requires an annual exportation of a considerable portion of the crop,[b] it is highly desirable that this product be prepared in every way free from deleterious substances which would interfere with its sale and use abroad.

During a recent study of the processes of curing and sulphuring hops[c] some experiments were made to determine the most probable source of arsenical contamination. The possible sources include fuels, arsenical sprays, the soil, and sulphur both when used in the field to destroy pests and when burned under the hops on the kiln during the drying process.

Since the open-fire, or "direct," process of drying is never used in this country, and as traces of arsenic have been found in hops not treated with insecticides, only the soil and sulphur were considered in these experiments, which, though not fully complete, have yielded results of so much importance to American hop growers that they are here presented in preliminary form.

ORIGIN OF SAMPLES OF HOPS EXAMINED.

The geographical distribution of hops containing traces of arsenic was first investigated. Dry commercial samples were obtained from England, Belgium, East Prussia (Altmark), Bavaria, Bohemia (Saaz), British Columbia, New York, Wisconsin, and the Pacific coast. Upon analysis[d] small quantities of arsenic (1.5 parts to the million, or less) were detected in samples from each of the regions just mentioned. These results indicate that hops from any of the hop-growing districts of the world may contain traces of arsenic, and suggest the necessity for the thorough examination of hops whatever

[a] Duncan, C., loc. cit., p. 24.

[b] Merritt, E. Bul. 50, Bureau of Statistics, U. S. Dept. Agriculture, table 5, p. 13.

[c] Stockberger, W. W. Farmers' Bulletin No. 304, U. S. Dept. Agriculture, 1907, pp. 19–26.

[d] Except when otherwise stated all analyses for arsenic were made in the Bureau of Chemistry, United States Department of Agriculture.

their geographical origin, as well as the desirability of a careful scrutiny of the methods of cultivation and curing used abroad, particularly those processes in which, contrary to the American practice, hops are dried over open fires.

EXAMINATION OF HOP SOILS.

Samples of soil from a number of American hop fields have been examined for arsenic,[a] but in no case has its presence been detected. However, these results do not necessarily prove the absence of arsenic from the soils of the fields examined, since the hop plant has a very extensive and deep-growing root system which might very readily explore soil layers unrepresented in the samples taken.

Since traces of arsenic have been found in unsulphured hops grown on some of the soils from which these samples were taken, it may be inferred that the samples were not representative of the true soil conditions as just noted or that arsenic may be present in the soil in quantities too minute to be detected by the ordinary methods of analysis, the larger and measurable quantity in the plant being due to gradual accumulation during the process of growth.

THE ABSORPTION OF ARSENIC BY THE GROWING PLANT.

Some early authors held that living plants did not absorb arsenic,[b] but numerous plants have been found to contain this substance,[c] which was doubtless derived from the soil. Nobbe[d] states that only a very small quantity of arsenic is taken up by plants, though according to Angell[e] plants of rhubarb, bean, rye, and buckwheat accumulate appreciable quantities from soils heavily fertilized with superphosphates. Davy[f] found arsenic in peas, cabbages, and Swedish turnips grown in soils mixed with superphosphates, 40 per cent of which Lyttkins[g] states contain arsenic, in amounts varying from 0.012 to 0.26 per cent as estimated by Stoklasa.[h] Collins[i] found that barley

[a] The analysis of the soil samples was made in the Bureau of Soils, United States Department of Agriculture.

[b] Targioni-Tazzetti, A. Ann. Sci. Nat., ser. 3, vol. 5, pp. 177–191, 1846.—Danberry, Chas. Quart. Jour. Chem. Soc., vol. 14, pp. 209–230, 1862.

[c] Pfeffer, W. Pflanzenphysiologie, 2 ed., vol. 1, pp. 432–433, 1897.

[d] Nobbe, F., Baessler, P., and Will, H. Landw. Versuchstat., vol. 30, p. 409, 1884.

[e] Angell, A. and A. F. Chem. and Drug., vol. 60, p. 430, 1902.

[f] Davy, E. W. Philos. Magazine, vol. 18, pp. 108–113, 1859.

[g] Lyttkins, A. Kgl. Landw. Akad. Handl., vol. 33, pp. 317–320, 1894.

[h] Stoklasa, J. Ztschr. Landw. Versuch. Oesterr., vol. 1, p. 154, 1898.

[i] Collins, S. H. Jour. Soc. Chem. Ind., vol. 21, pp. 222–223, 1902.

grown on soils containing arsenic may accumulate large amounts of this element, most of which, as has been further shown by pot experiments,[a] occurs in the barley grains. Likewise, Gosio [b] records the accumulation of arsenic in the leaves, stems, and fruits of squash plants which had been watered with dilute arsenic solutions.

In order to test the capability of the hop plant to take up arsenic from the soil, two adjoining plats of sixty hills each were selected in a hop yard and from May 24 to August 5, 1907, the alternate hills of one plat were watered weekly with solutions of arsenious acid and those of the other with solutions of arsenic acid. Each solution was made up in five different strengths, the arsenious acid ranging from 0.01 to 1 per cent and the arsenic acid from 1 to 3 per cent. Solutions of each acid were then applied to fifteen groups of two hills each in amounts so regulated as to form a gradually increasing series. In this way the total amount of arsenious acid administered to the plants of each hill ranged from one-tenth of an ounce to 24 ounces and the arsenic acid from 2 to 20 ounces to each hill. When the hops were mature, those from each group of two hills which had received the same treatment were gathered separately, dried without sulphur, and prepared for chemical examination.

Upon analysis traces of arsenic, from 0.5 to 3 parts per million, were found in each sample examined. While the amount of arsenic in various samples was not in direct proportion to the amount administered to the plant, the balance of evidence is in that direction. Necessarily the experimental error is very large, but when due allowance is made for it the results warrant the conclusion that hops will take up from soils containing available arsenic amounts relatively proportional to the quantity contained therein.

IMPURE SULPHUR AS A SOURCE OF ARSENIC.

That the sulphur used in sulphuring hops frequently contains small quantities of arsenic is quite generally known and has been suggested as the source of the arsenic occasionally found in dried hops.[c] However, analysis of the different grades of sulphur in common use indicates that from the quantities applied in most cases sufficient arsenic would not be produced to account for the traces sometimes found in hops, provided it was uniformly distributed through them. Analysis shows that there is often wide variation in the amount of arsenic contained in samples drawn from different bales

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[a] County Councils Cumberland, etc. Tech. Education Rept., vol. 10, pp. 1–121, 125–150, 1901.

[b] Gosio, B. Atti r. Accad. Lincei, vol. 15, pp. 730–731, 1906; abstract in Centbl. Bak. Par. u. Infek., part 2, vol. 18, pp. 724–725, 1907.

[c] Rüffer, E. Wochenschr. f. Brauerei, vol. 18, p. 109, 1901.

of the same lot in which all the hops were grown and dried under practically the same conditions, and also in samples drawn from different portions of one and the same bale.

This apparent contradiction may be explained on the assumption that the arsenic volatilized by the burning of the sulphur is deposited on the layers of hops next the floor of the kiln while the upper layers remain practically free. To test this theory, a series of experiments was made with a small kiln in which different lots of hops were separately exposed to the fumes of equal amounts of the different grades of sulphur, after which samples were carefully taken from the top and bottom layers before the hops were removed. The experiment was repeated with double the quantity of each grade of sulphur used before. For comparison, a certain quantity of arsenious oxid was added to the sulphur, with which a final lot was treated.

The preliminary results of these experiments fully support the theory that arsenic may be transferred from sulphur to hops and unequally distributed therein. The analysis of the samples shows in practically every case a very appreciable difference between the amounts of arsenic deposited in the upper and lower layers of the hops. The evidence further indicates that the greater portion of the arsenic is deposited in the bottom layer. The variation in the results obtained with the different grades of sulphur was less than was anticipated, since each grade apparently increased materially the arsenic content of the hops.

Although each test was repeated, using double the amount of sulphur, the relative proportion of arsenic present was not constant. However, the results indicate that a larger arsenic content may be expected when the proportion of sulphur used is increased.

The samples from the last experiment, in which arsenious oxid (the white arsenic of commerce) was added to the sulphur, contained relatively large quantities of arsenic, twelve times as much being found in the hops of the bottom layer as in those of the top layer.

CONCLUSIONS.

From the foregoing experiments the following conclusions are drawn:

(1) Traces of arsenic may occasionally be found in dried hops irrespective of their geographical origin.

(2) If available arsenic is present in the soil it may be taken up by the hop plant under favorable conditions.

(3) Except in rare cases the amount of arsenic derived from the soil by the hop plant is probably smaller than 0.01 grain per pound of dry hops, which is the smallest amount regarded as deleterious by the Royal Commission on Arsenical Poisoning in England.

(4) By the use of impure sulphur during the process of curing, hops may be contaminated with arsenic, which will be concentrated in the lower layers on the kiln floor with the result that certain samples may show an amount greater than 0.01 grain per pound.

(5) The probability of hops acquiring arsenic from what seems to be a very ready source may be much lessened by employing only the very highest grades of purified sulphur in hop curing, and the quantity used should be reduced to the lowest possible limit.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 121, PART V.

B. T. GALLOWAY, *Chief of Bureau.*

APPLE LEAF-SPOT CAUSED BY SPHAEROPSIS MALORUM.

BY

W. M. SCOTT, PATHOLOGIST,

AND

JAMES B. RORER, ASSISTANT PATHOLOGIST,

INVESTIGATIONS OF DISEASES OF FRUITS.

ISSUED MARCH 12, 1908.

WASHINGTON:
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ILLUSTRATIONS.

B. P. I.—342.

APPLE LEAF-SPOT CAUSED BY SPHAEROPSIS MALORUM.

By W. M. Scott, *Pathologist*, and James B. Rorer, *Assistant Pathologist, Investigations of Diseases of Fruits.*

INTRODUCTION.

The disease of apple leaves known as "brown-spot," "frog-eye," "leaf-blight," or "leaf-spot" is very common throughout the eastern United States. As these names suggest, the disease is characterized by circular or irregular reddish brown spots with slightly raised purplish margins. (Pl. III, fig. 1.) These spots when first visible to the naked eye are very minute and purple, but rapidly increase in size until they attain a diameter of from one-eighth to one-half inch, while the affected tissue becomes brown and later sometimes gray. The mature spots are usually circular, but after midsummer may become more or less irregular or distinctly lobed in outline, a condition apparently brought about by a secondary extension of the disease from two or more points on the margin of the original circular spot. If the infection is bad, a number of spots may coalesce and form large brown patches involving half the leaf or more, but in these dead areas the margins of the individual spots usually remain distinct.

These spots should not be confused with those produced on apple leaves by the apple-blotch Phyllosticta. The latter are yellowish and minute, never more than one-sixteenth of an inch in diameter, and will not be considered in this paper.

Leaf-spot is of greater economic importance than is generally supposed. It makes its first appearance early in the spring as the leaves are unfolding, and infections take place continuously throughout the growing season. As a result of its attacks trees may become completely defoliated from six weeks to two months before the normal period of leaf fall. If this is repeated for a series of years, the trees become weakened and the life of the whole orchard is materially shortened. Moreover, the fruit from such prematurely defoliated

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trees is small and of poor quality, and the fruit buds must necessarily go into the dormant stage in a rather immature condition, often resulting in a partial or complete failure of the next year's crop.

CAUSE OF LEAF-SPOT.

Considerable confusion has existed as to the cause of this leaf-spot disease. Though no inoculation experiments have been reported, the disease has generally been conceded to be of fungous origin and has commonly been attributed to *Phyllosticta pirina* Sacc., and less commonly to *Phyllosticta limitata* Pk. and *Sphaeropsis malorum* Pk., while species of Hendersonia, Pestalozzia, and other fungi have been reported as occurring on the diseased areas.

The disease in its economic aspect was first mentioned by Alwood [1] [a] in 1892, when he described a "brown-spot" of apple foliage and reported a serious outbreak in the Virginia orchards during the preceding summer. He attributed the trouble doubtfully to *Phyllosticta pirina.*

In 1895 Kinney [2] cited the same fungus as the cause of apple and pear leaf-spots in Rhode Island.

Stewart,[3] in 1896, reported a serious outbreak of leaf-spot on Long Island caused by an undescribed fungus which Peck named *Phyllosticta limitata.*

In 1898 Alwood [4] again recorded the common occurrence of *Phyllosticta pirina* on leaf spots, but found *Sphaeropsis malorum* Pk. and *Hendersonia mali* Thüm. associated with it.

Lamson,[5] in 1899, gave *Phyllosticta pirina* as the cause of "brown-spot" of apple foliage in New Hampshire, while Corbett,[6] in 1900, described a "brown-spot," or "frog-eye," in West Virginia due to the same fungus.

In 1902 Stewart and Eustace [7] questioned the parasitism of *Phyllosticta pirina* and *P. limitata.* In their opinion "at least a large part of the so-called apple leaf-spot is due to spray injury and weather conditions and not to fungous origin." They suggest that the fungi in question live saprophytically on leaves injured by Bordeaux mixture and arsenical sprays, or in the case of unsprayed trees on leaf-spots which are in some way the result of atmospheric influences. A possible explanation for the formation of the spots is "when a shower is followed by bright sunshine, drops of water on the leaves act as lenses and concentrate the sun's rays to such an extent as to overheat the tissues underneath."

In 1902 Clinton [8] recorded *Sphaeropsis malorum* as the cause of brownish spots on apple leaves in Illinois "much like those of the

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[a] The serial numbers used in this paper refer to the bibliography, which will be found on page 54.

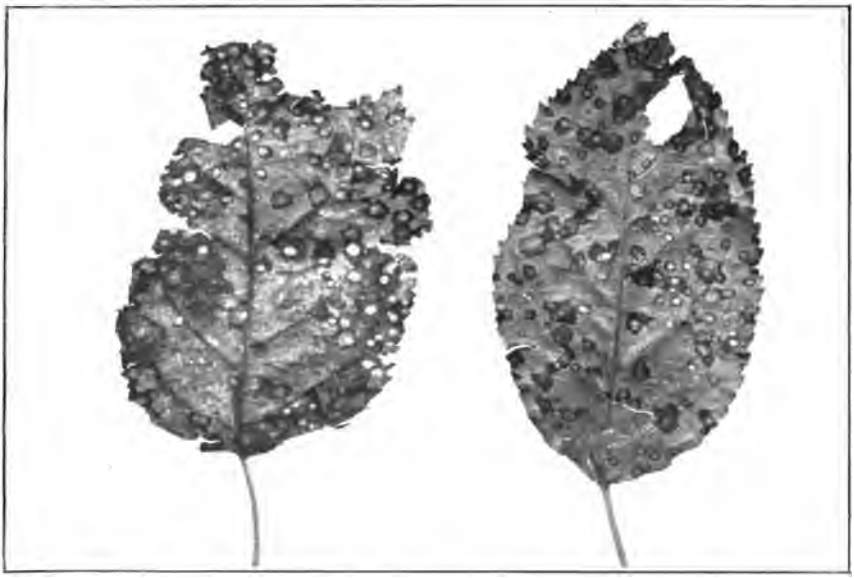

FIG. 1.—APPLE LEAVES SHOWING LEAF-SPOTS PRODUCED BY NATURAL INFECTION.

FIG. 2.—APPLE LEAVES SHOWING LEAF-SPOTS PRODUCED BY INOCULATION WITH SPHAEROPSIS MALORUM PK.

leaf-spots or Phyllostictae fungi, but are apt to be more irregular and larger." The same author,[9] in 1903, stated that most of the apple leaf-spot troubles in Connecticut were due to this same fungus.

Stone and Smith,[10] 1903, in accounting for a serious outbreak which occurred in Massachusetts the previous year say "there can be no reasonable doubt that frost was the destructive agency." They observed that the spotting of the leaves continued throughout the summer, and that even as late as August spots as a result of spring frost developed on leaves which had not previously shown the injury.

Sheldon,[11] in 1907, transferred the fungus *Phyllosticta pirina* Sacc. to the genus Coniothyrium on account of the dark color of the spores and proposed the name *Coniothyrium pirina* (Sacc.) Sheldon. From an examination of herbarium material and fresh specimens from different parts of the eastern United States there is no doubt that the fungus commonly called *Phyllosticta pirina* in this country is a Coniothyrium. Apparently mature spores from a European specimen of *Phyllosticta pirina* in the herbarium of the Department of Agriculture are hyaline and ellipsoid, agreeing with the original description of Saccardo,[12] so that his species may prove to be autonomous.

In view of the conflicting statements and apparent uncertainty as to the cause of apple leaf-spot, the writers during the summer of 1906 and 1907 made a study of the disease in connection with demonstration spraying work in the Ozarks. It was found that *Sphaeropsis malorum*, contrary to the general belief, is the cause of the disease.

CULTURAL STUDIES.

A somewhat cursory examination of a large amount of leaf-spot material collected in Arkansas during 1906 showed that there was no one fungus which fruited constantly on the spots. The pycnidia of *Coniothyrium pirina* (Sacc.) Sheldon were found perhaps more commonly than any other, but two species of Pestalozzia and one each of Coryneum, Hendersonia, and Alternaria occurred frequently, while occasionally the pycnidia of *Sphaeropsis malorum* and a species of Septoria were met with. The same was true of specimens received from Missouri, Nebraska, New York, Maryland, Virginia, and West Virginia. Pure cultures of all of these fungi were easily obtained by the poured-plate method. All grew well and fruited abundantly on apple agar or sterilized apple wood.

In the early part of the season of 1907 cultures were obtained from leaf spots by a somewhat different method. During the first spring outbreak of the disease, spots of various sizes, together with a little of the surrounding healthy tissue, were cut from the leaf and placed in a solution of mercuric chlorid (1–1,000) for two or three minutes. The bits of leaf were then thoroughly washed in sterile water and

transferred to slanted apple or potato agar. The writers separately made many sets of cultures by this method, using spots from leaves of Ben Davis, Winesap, and White Pearmain trees. Within a few days by the aid of a hand lens hyphæ could be seen growing out from the center or margins of the small spots. Mycelium developed rapidly and in about two weeks spores were formed, so that the fungi could be identified. The results were uniformly the same. In all cases in which the youngest spots, that is, those one-sixteenth of an inch or less in diameter, were used, the fungous growth was a pure culture of *Sphaeropsis malorum* Pk. In cultures made from the older spots, in which the central tissue had become brown, sometimes a pure Sphaeropsis was obtained, but more often a mixture of things. *Coniothyrium pirina* developed about as commonly as Sphaeropsis, both species often growing from the same spot. In addition to these two fungi, two species of Alternaria, a Cladosporium, bacteria, and yeasts were frequently present.

This cultural work, frequently repeated, gave evidence that *Sphaeropsis malorum*, always developing from the youngest spots, was the specific cause of the disease and that the other organisms were mere concomitants. Of course, to prove this inoculation experiments were necessary. These were made as soon as pure fruiting cultures of the different fungi were obtained.

INOCULATION EXPERIMENTS.

A number of different sets of inoculations were made, but the method of procedure was the same in each case. With a sterile needle the fruiting fungus was scraped from the surface of the agar and transferred to a tube of sterile water. In cases where pycnidia were present these were crushed against the side of the tube with a sterile glass rod to set free the spores. In order to ascertain the presence of mature spores a hanging drop of the fluid was always examined microscopically. This spore-bearing liquid was then sprayed on both surfaces of clean young leaves with an atomizer. Trees in more or less isolated young orchards were selected, and no two fungi were used on the same tree. From 20 to 40 leaves on two or three different shoots were involved in each inoculation. Checks were always made on separate trees by spraying 40 or 50 leaves with sterile water.

The first inoculations were made on May 28, 1907. The fungi used were *Sphaeropsis malorum*, and the undetermined species of Coryneum, Hendersonia, and Alternaria previously mentioned. It was raining at the time and the weather continued wet for several days.

On June 3, 1907, purple specks were appearing on the leaves which had been inoculated with Sphaeropsis, and on June 18 these leaves were badly affected with leaf-spot. (Pl. III, fig. 2.) On a twig bearing 30 leaves, 12 showed a dozen or more well-developed spots, and a few of these leaves had from 80 to 90 spots each. Twelve other leaves on the same branch had from 2 to 10 spots each, while only 6 remained free from the disease. On another branch 12 out of 20 leaves were badly affected.

With the exception of an occasional spot, evidently resulting from natural infection, the leaves sprayed with spores of the other fungi, as well as those sprayed with sterile water as a check, remained free from the disease.

Another experiment was made on June 19, 1907. Spores of *Sphaeropsis malorum*, *Coniothyrium pirina*, Coryneum, and Alternaria were used. The work was done at sunset following a shower, so that the leaves were wet. Again the leaves inoculated with the spores of *Sphaeropsis malorum* soon became badly affected with the characteristic leaf-spot disease, while the others, including the checks, developed no more than an occasional spot.

Another test was made with Sphaeropsis alone. The young leaves of a 2-year-old tree were inoculated during a period of dry weather in mid-June. The spores were sprayed on the leaves at about 10 o'clock, while the sun was shining brightly. At the same time sterile water was sprayed on the leaves of an adjacent tree as a check.

Though no rain fell for at least six days after the spraying was done, numerous purple specks began to appear on the inoculated leaves within a week and soon developed into the characteristic brown spots. A few spots, never more than one to a leaf, appeared on the checks. The mature spores of Sphaeropsis germinate so rapidly that in dry weather the dews provide sufficient moisture for leaf infection, as indicated by this experiment.

Inoculations made on June 26, 1907, with *Sphaeropsis malorum*, Coryneum, and Alternaria gave results similar to those previously recorded for these fungi. From 20 to 50 spots developed on each of the leaves inoculated with Sphaeropsis, while only a few scattered spots occurred on the leaves of the check and on those sprayed with spores of the other fungi.

On August 4, 1907, inoculations with Coniothyrium were again tried. Leaves on rapidly growing 2-year-old Ben Davis trees in a nursery were used. The spores were obtained from a fresh culture and were so numerous that they clouded the liquid. The work was done during a light shower and some rain fell the next day.

The same experiment was repeated on the evening of August 14, 1907. Though it did not rain at this time the trees were wet down with sterile water on the following night.

Again, on August 21, 1907, this same fungus was used for inoculations, which were made in the evening just after a heavy rain. For the next two days the sky was overcast and occasional showers fell.

The results of these three sets of inoculations with Coniothyrium were negative. Spots were found here and there on the inoculated leaves, but no more than on the checks which were sprayed with sterile water. Similar spots, never more than two to a leaf, were found throughout the nursery at this time and were evidently produced by a natural infection with Sphaeropsis.

CONCLUSIONS.

The following conclusions may be drawn from the results of the inoculation experiments described in the preceding pages:

Sphaeropsis malorum Pk., the black-rot fungus, is parasitic on apple leaves, producing circular (or irregular) reddish brown spots an eighth of an inch or more in diameter, and is undoubtedly the cause of the apple leaf-spot disease which occurs in the middle West. The common apple leaf-spot disease of the Eastern States, being so similar in every respect, is doubtless caused by the same fungus, although some other fungi may possibly produce similar spots.

Coniothyrium pirina (Sacc.) Sheldon, although it occurs abundantly on apple leaf-spots, appears to have nothing to do with their formation.

The several other fungi that were tested, such as *Hendersonia* sp., *Coryneum* sp., *Pestalozzia* sp., and *Alternaria* sp., proved to be nonparasitic in these experiments and probably occur on leaf spots only as saprophytes.

SOURCE OF INFECTION.

Sphaeropsis malorum is perhaps the most common fungus that inhabits pome-fruit orchards east of the Rocky Mountains. It is the cause of the black-rot of the apple, the pear, and the quince and produces cankers on trunks and branches of these fruit trees. It occurs abundantly on dead twigs and branches in nearly every orchard, producing spores in enormous numbers. This is perhaps the most fertile source of infection for both fruit and foliage. In old orchards, particularly where pruning is neglected, the leaf-spot disease is much worse than in young orchards. The leaves of young trees adjacent to an old orchard become more spotted with the disease than those farther removed. Another source of infection is the diseased fruits of the previous year's crop. Although the fungus fruits only sparingly on leaves on the tree, it produces fertile pycnidia in considerable numbers on these leaves after they have fallen to the ground.

FIG. 1.—UNSPRAYED WINESAP TREES DEFOLIATED BY THE LEAF-SPOT DISEASE.

FIG. 2.—SPRAYED WINESAP TREES IN FULL FOLIAGE, LOCATED IN THE SAME ORCHARD AND PHOTOGRAPHED AT THE SAME TIME (OCTOBER 19, 1906) AS THOSE SHOWN IN FIGURE 1.

TREATMENT.

Since 1892, when Alwood[18] first recommended Bordeaux mixture as a preventive for apple leaf-spot, other writers have advocated the same method of treatment. The prevention of this disease has been one of the most striking results of various spraying experiments and demonstrations conducted by the Bureau of Plant Industry. Waite, in 1901, in connection with bitter-rot experiments in Virginia, controlled the disease with two applications of Bordeaux mixture. His recommendations in Farmers' Bulletin No. 243, p. 19, are based upon this work. Similar results were obtained by Scott[14] in Virginia in 1905. In the spraying demonstrations in the Ozarks during 1906 and 1907 the writers found that the spraying ordinarily necessary for the protection of the fruit from fungous attacks[a] will usually control this leaf trouble without any additional treatment. During both seasons unsprayed trees were shedding their leaves by August 1 and were completely defoliated by the middle of September, while the sprayed trees remained in full foliage until the first killing frost. (Compare Pl. IV, figs. 1 and 2.) In addition to the injurious effect upon the trees this premature defoliation caused the fruit to be small and of poor quality as compared with that from sprayed trees. An average barrel of Winesaps from sprayed trees contained 612 apples, while 731 from unsprayed trees in adjacent rows were required to fill a barrel.

For the control of this disease alone, without reference to the diseases of the fruit, an application of Bordeaux mixture should be made in the spring a week or ten days after the petals have fallen, a second application four weeks later, and a third about four weeks after the second. Three applications are necessary only in exceedingly wet seasons in sections where the disease is severe. Ordinarily two treatments, one about three weeks after the petals are off and the other four or five weeks later, are sufficient.

A weak Bordeaux mixture, such as 3 pounds of copper sulphate and 3 pounds of lime to 50 gallons of water, is effective in controlling this disease, Bordeaux mixture of full strength not being required.[b]

[a] For a combination treatment for the leaf-spot disease, the diseases of the fruit, and the codling moth, see Farmers' Bulletin No. 283, pp. 41–42.

[b] For various formulas and methods of preparing Bordeaux mixture, see Farmers' Bulletin No. 243, pp. 5–10.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 121, PART VI.

B. T. GALLOWAY, *Chief of Bureau.*

THE IMMUNITY OF THE JAPANESE CHESTNUT TO THE BARK DISEASE.

BY

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PATHOLOGIST IN CHARGE OF THE LABORATORY OF FOREST PATHOLOGY.

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THE IMMUNITY OF THE JAPANESE CHESTNUT TO THE BARK DISEASE.

By HAVEN METCALF, *Pathologist in Charge of the Laboratory of Forest Pathology.*

THE EXTENT OF THE BARK DISEASE.

The bark disease of the chestnut, caused by the fungus *Diaporthe parasitica* Murrill, has spread rapidly from Long Island, where it was first observed, and is now reported from Connecticut, Massachusetts, Vermont, New York as far north as Poughkeepsie, New Jersey, Pennsylvania, and possibly Delaware. It is no exaggeration to say that it is at present the most threatening forest-tree disease in America. Unless something now unforeseen occurs to check its spread, the complete destruction of the chestnut orchards and forests of the country, or at least of the Atlantic States, is only a question of a few years' time.

AN IMMUNE VARIETY.

Observations made by the writer during the past year indicate that all varieties and species of the genus Castanea are subject to the disease except the Japanese varieties (*Castanea crenata* Sieb. and Zucc.). All of the latter that have been observed in the field or tested by inoculations have been found immune. This fact can hardly fail to be of fundamental importance to the future of chestnut nut culture. Although the nuts are distinctly inferior in flavor to the European varieties, such as Paragon, the Japanese chestnut is already grown on a large scale as a nut-producing tree. There are, however, many trade varieties of dubious origin. Some of these may prove later to be subject to the disease. Immunity tests of all known varieties of chestnuts have been undertaken.

Attempts will also be made to hybridize the Japanese with American and European varieties, with the hope of combining the immunity of the former with the desirable qualities of the latter.

However excellent as a nut and ornamental tree, the value of the Japanese chestnut as a forest tree is doubtful. It can be recommended only experimentally at present for forest planting. It certainly will not take the place of the American chestnut. The tree is said to attain a height of 50 or 60 feet in Japan. As seen in this country it is a handsome tree, dwarfish and compact in habit, and rather slow growing. It has hardly had time to show how large it can grow.

The immunity of the Japanese chestnut, together with the fact that it was first introduced and cultivated on Long Island and in the very locality from which the disease appears to have spread, suggests the interesting hypothesis that the disease was introduced from Japan. So far, however, no facts have been adduced to substantiate this view.

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